Biological Studies in Hawaiian Water-Loving Insects

PART I
Coleoptera or Beetles

PART II
Odonata or Dragonflies

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(Presented at the meeting of Dec. 5, 1935)

FOREWORD

This work was done at intervals, as opportunity offered, during the past six years and concerns chiefly the Island of Oahu, on which is the city of Honolulu. Numerous excursions into the field were made. Some of these were incidental to Experiment Station business. Very scant observations were made on the Island of Kauai, and hardly more, on the Island of Maui. A certain amount of data were obtained from the lowlands of Molokai, while late in 1933, the writer was fortunate in being able to spend a week at the Puuohoku Ranch, at the eastern end of that island and, in company with his brother, engaged in engineering work, to penetrate well into the rugged mountains and explore stream and waterfall. On the large Island of Hawaii, with an area of 4,015 square miles and mountains rising to nearly 14,000 feet, observations on water-loving insects were made in various scattered localities, and more at length and in detail when in the fall of 1931, in company with Mr. O. H. Swezey, about a week was spent at the forest nursery at Nauhi Gulch, at an elevation of 5,200 feet on the slopes of Mauna Kea, the summit of which, altitude 13,784 feet, was also visited.

Thanks are due to Mr. O. H. Swezey for assistance both in the field and in the laboratory; to Mr. E. H. Bryan, Jr., for identifying various Diptera; to Dr. H. L. Lyon for determining plants, chiefly aquatic and subaquatic; and to Mr. Twigg-Smith, illustrator for the Experiment Station, H.S.P.A., and to his assistant, Mr. J. Yamamoto, for a very considerable amount of illustrative

work. The writer is indebted also to other gentlemen outside of the Territory of Hawaii, for which acknowledgment is made in the proper places in the text. The "Fauna Hawaiiensis," by various authors, but chiefly those parts by Dr. R. C. L. Perkins, who spent years in the Islands collecting and studying the material for the "Fauna," has proved invaluable. I have also gained much information from the two excellent books—"Dragonflies of North America" (1929), by Needham and Heywood, and "Biology of Dragonflies" (1917) by Tillyard. No attempt has been made to do justice to the immense amount of literature on aquatic and semi-aquatic insects.

Part I deals with 7 species of beetles that spend a considerable part of their existence in the water. Part II is less complete, as only about half of the 30 species of dragonflies are dealt with at any length. The flies or Diptera, the bugs or Hemiptera and the single species of Lepidoptera, *Nymphula fluctuosalis* Zell., the caterpillar of which is aquatic, are being worked up and, it is hoped, will appear in good time.

The writer is not a specialist in any of these groups and he has endeavored to deal with the subject mainly from a biological standpoint, leaving alone as far as possible, questions of phylogeny and taxonomy.

INTRODUCTION

The Hawaiian Islands arising as volcanoes from the sea and exceedingly remote from the nearest large land mass, received through the course of ages the chance insect migrants that have evolved into the highly interesting though naturally rather unrepresentative entomological fauna of today. Unrepresentative, in that where a section of an average continental fauna has the major groups—orders and families—of insects reasonably well represented, in Hawaii with its oceanic fauna, certain of these major groups are entirely lacking—at least as native insects—others may be barely present, or be represented frequently by few genera with a large number of species.

Water-loving insects are not a rich group in the Hawaiian Archipelago. Here are no may-flies (Ephemerida), no stone flies (Plecoptera), no caddis flies (Trichoptera), nor any aquatic Neuroptera although conditions for their existence seem favorable. The beetles and bugs are few in number and generally of no great

interest, the moth, the caterpillar of which is a rice pest in parts of the Orient, is adventitious here. The flies though rather indifferently represented and not very well known are of considerable interest, certain ones, as species of Chironomidae and Dolichopodidae being adapted to special environment. It is in the Odonata, suborder Zygoptera or damselflies that we find the greatest development among our aquatic insects; in fact some of these have ceased to be truly aquatic in their nymphal stages, the forested ridges on which they live often being devoid of streams and pools. Those damselfly nymphs that live in the water usually favor a certain environment there and from the most aquatic to the terrestrial species of nymphs there exists a pretty good series of intermediate forms connecting the one with the other.

To gain a fair knowledge of which Hawaiian insects spend all or part of their existence in or on the water, bogs, puddles, ponds, reservoirs, ditches, flumes, clear mountain streams with their wet banks and waterfalls, foul-smelling waters of the lowlands, maritime marshes, the sea itself, tree and rock holes containing water, water at the leaf bases of plants, dense fern cover—all must be investigated. Even sewage should not be exempt from search. It may be pleasanter of course, and generally more profitable to work the more upland districts for, quite apart from matters of shade and more aesthetic surroundings, the water-loving insects of mountains and canyons are chiefly endemic (native), they exist in greater variety there and often show remarkable adaptation to their environment. In the lowlands nevertheless, there is much of interest in and about water. The following is a mere sketch of the environmental distribution of our water-loving insects. It will be noted that the life zones are not always well defined and that a number of the insects range from sea-level to waters more than a mile above it. Moreover, the same species may inhabit both fresh and brackish water.

The bather at Waikiki, Honolulu, may have observed the wingless, salt water strider bug, *Halobates sericeus* Esch. as it races over the surface of calm waters at his approach, or at rare intervals, when it is beached in numbers during rough inshore weather.

About wet sand, rocks and splash pools of the seashore occur a few flies of the families Ephydridae, Canacidae and Dolichopodidae, as well as two marine midges (Chironomidae *sens. lat.*)

recently brought to light. Rusty red mites (acari) and tiny collembolous insects explore the rocks by the sea.

One often finds just behind the beach, shallow brackish ponds evaporated to a salinity even exceeding that of sea water and set in an area of the succulent Pickle weed or *akulikuli kai, Batis maritima* Linn. Here despite small minnows the prettily mottled water boatman bug, *Trichocorixa blackburni* (White) is to be seen in all stages. Its eggs, small and whitish, are glued to submerged objects and may be conspicuous on the erect little *Potamogeton* seedling plants, hardly thicker than a thread. Rarely was *Trichocorixa* found in mountain waters. Common on dirty brown felt-like mats of blue-green algae, chiefly *Phormidium* sp. but with small numbers of *Lyngbya* and *Anabaena,* is the little spotted wing *Scatella sexnotata* Cresson fly as well as a borborid fly, *Leptocera* sp. The large pale gray dolichopodid fly *Hydrophorus pacificus* Van Duzee and the little hydrophilid beetle *Enochrus nebulosus* (Say) frequent brackish as well as quite fresh lowland waters. Passing now to shallow maritime marshes where the water is less brackish to quite fresh, to old rice fields, taro patches, lowland reservoirs, rain pools, etc., we note a considerable increase in the aquatic fauna. Here and there near the water's edge one often sees the rather large predacious anthomyid fly, *Lispa metatarsalis* Thomson resting or moving about in an alert manner. Its larva, likewise predacious, is semiaquatic or even aquatic under certain conditions. The insect however, occurs also beside little streams in mountain forests. The far-ranging *Brachydeutera hebes* Cres., a large ephydrid fly is now conspicuous. *Scatella* may occur in swarms, and *Hydrophorus* is numerous. The night mosquito *Culex quinquefasciatus* Say is in this environment as well as at considerable altitudes while the mosquito-like *Chironomus hawaiiensis* Grims. is one of the most abundant lowland insects in fresh water, its bloodworm larva on muddy bottoms or in thick growths of green algae serving as food for more powerful aquatic insects. Along muddy shores a little carabid beetle (*Bembidion niloticum batesi* Ptz.)[1] is often abundant. About weedy and sometimes malodorous shallows we find the *Enochrus* beetle plentiful, and often its distant relative, the larger very convex black *Coelostoma fabricii* (Montr.) in smaller numbers. Both are foreign insects. Here too may occur

[1] Determined by Dr. E. C. Van Dyke.

the tiny dytiscid beetle *Hydrovatus confertus* Sharp, while its larger relative *Rhantus pacificus* (Bdv.) prefers deeper and more open waters from near the shore to far into the cool uplands. The two widely distributed dragonflies *Anax junius* Drury and *Pantala flavescens* (Fab.) breed here, their empty nymphal shells being often found clinging to reeds and to *Herpestis* plants. The black-marked *Tramea lacerata* Hagen dragonfly, also exotic, is less plentiful. Its nymphs have been taken in lowland plantation reservoirs where lives also the native damselfly, *Megalagrion xanthomelas* (Selys). The back-swimming water bug *Buenoa pallipes* (Fab.) belongs more properly to these lowlands but is found also in canyon pools. The three little water-running bugs: *Mesovelia mulsanti* White, *Merragata hebroides* White, and *Microvelia vagans* (White) may all be present on one body of water; the first species, recently noted here, seems altogether a lowland insect, the second is essentially so, while *Microvelia* appears equally at home in the lowlands as it does a mile or more above the level of the sea.

In these sun-heated, often stagnant and shallow lowland waters, frequently matted with algae and occasionally ill-smelling with decaying vegetation, tiny organisms—the Protozoa or one-celled animals, Rotifera, the bryozoan *Plumatella,* various, usually small worms or vermes, the minute Crustacea (the clam-like Ostracoda, the swift-darting Copepoda, and the clouds of Cladocera)—all may exist in countless numbers. Probably most or all of these together with the prolific *Chironomus* bloodworm serve as food for the aquatic young of many insects and for some insects throughout their life.

In malodorous or in sewage waters we find the rat-tailed maggots *Lathryophthalmus arvorum* (Fabr.) that produce shrill-humming, bee-like flies, and Psychodidae or moth flies. Here too the viviparous snail *Melania* may be exceedingly abundant.

This exuberance of water life however is often of brief duration. The struggle for existence is usually severe, and where mosquito fish—top minnows or killifish—gain entrance, as they eventually do in most lowland waters, the invertebrate fauna suffers accordingly. And here a swamp dries up for the season or for longer, and there a reservoir is drained. Pools becoming smaller and smaller ever crowd their diverse tenants, an orgy of feasting and cannibalism results; some of the forms survive to com-

plete their transformations but many others perish miserably in the sun-baked mud. With the return of the waters, aquatic life must commence anew.

In the moister forests and uplands, the streams, the bogs, the several plant species that conserve moisture in their leaf axils, as well as the moss-like growth and the wet trash beneath the undercover—all these being in a region of greater rainfall and shade and often less disturbed by man, support in better equilibrium a modest though interesting water-loving fauna. A large number of dolichopodid flies of the genus *Campsicnemus* occur in damp places in the mountains and are often found skating on pools there. A fewer very active species perform regularly on gently running water. Other *Dolichopodidae* such as the large *Dolichopus exsul* Aldrich frequent wet banks and water margins and at least one species may breed at the leaf axils of plants. *Brachydeutera hebes* is still with us, patronizing stagnant pools and occasionally breeding in a tree hole along with the common day mosquito, *Aedes albopictus* (Skuse) and the large moth fly, *Telmatoscopus albipunctatus* (Will.). *Scatella* flies of more than one species frequent wet rocks and also mountain flumes and ditches. The larva of *Scatella* developing, not or barely awash among algae and diatomaceous growth, are sought by a slow-moving little figitid wasp that parasitizes it. *Tanytarsus lacteiclavus* Grims., a small pale green midge hovers in lazy swarms over the water, its tube-constructing larva dwelling therein. A very few ceratopogonid midges are aquatic or subaquatic here, the larvae of other midges breeding in the mossy forest at greater altitudes in the leaf axils of certain plants[2] and among damp moss and debris. The curious dusky midges of the genus *Telmatogeton* (= *Charadromyia*) frequent torrents, waterfalls and swift ditch and flume waters, which they sometimes follow to low levels. The long-legged limnobiid flies have subaquatic species that in their early stages dwell on dripping wet banks or among old water-soaked leaves. Three water beetles—*Rhantus, Copelatus* and *Limnoxenus*—are more characteristic of the uplands where they are often found in the little disconnected pools that constitute the very headwaters of streams. The mountain dragon-

[2] When the *ieie* vine (*Freycinetia arborea* Gaud.) is in fruit, the wet pasty material at the base of the cones that are embraced cup-like by the short and rather widely spreading red leaf bracts, may be periodically covered by rain water. Thus is its chiefly dipterous fauna adapted to a subaquatic life.

fly, *Nesogonia blackburni* (McLachl.) and the giant *Anax strenuus* Hagen are more properly upland species. Nearly all the zygopterous Odonata or damselflies are forest insects and are of the greatest interest. The small, water-running bug *Microvelia vagans,* so destructive to *Tanytarsus* midges, as these delicate insects are emerging from the water, is everywhere abundant on mountain waters to an altitude of at least a mile.

Streams of the uplands are subject to certain vicissitudes, and thus is their fauna affected favorably or otherwise. With one of the little streams behind Honolulu in mind, changes may occur somewhat as follows: During dry periods, the waters considerably diminished in their upper reaches, separate into little pools or remain connected one with the other by a very thin flow. Pools thus rendered stagnant favor an abundant growth of filamentous green algae such as *Cladophora,* and here certain of the Nematocera or lower flies may breed extensively and so too, their enemies. The region abounds in the small trees of the common guava (*Psidium guajava* Linn.) the large yellow fruits of which seasonally litter certain trails and befoul pools, thus creating suitable habitats for the rat-tailed maggot which is the larva of the large bee-like syrphid fly (*Lathryophthalmus arvorum* (Fab.). *Culex* and *Brachydeutera* will also breed here. The decaying guavas along the forest paths are often reddish brown with countless numbers of the common pomace fly, *Drosophila melanogaster* Meigen, that through force of circumstances may occasionally be subaquatic in the immature stages. On the well tenanted pools may be crowds of the *Microvelia* bug, while along the margin or among dense algae is the savage larva of the *Limnoxenus* water beetle and perhaps an occasional larva of a dolichopodid fly. In its depth may be the nymph of the mountain dragonfly *Nesogonia,* and perhaps of two or three damselflies. In time, the succulent trailing weed "honohono" or *Commelina nudiflora* Linn. grows very rankly, sometimes choking up large portions of the stream bed and thus quite concealing the water. But when the rains commence, pools unite as the stream swells and finally, after one or two heavy downpours, the invading vegetation is swept aside, boulders may be shifted and debris taken away or deposited so that the stream fauna suffers.

Inhabiting mountain streams, even above large waterfalls, are the little native shrimp (*Atya bisulcata* Randall) and one or more

species of gobies or *oopu*. The shrimp seems harmless to insect life but the gobyfish devours quantities of the larvae of chironomid midges and other organisms.[1] Trout have been introduced into streams on the Island of Kauai. The trout is a voracious feeder on aquatic insects, and in New Zealand where it was brought in years ago, it has nearly exterminated certain water insects there.

Aquatic snails common in the lowlands may also be plentiful in mountain streams. A very tiny species somewhat like a limpet in form of shell is *Ancylus sharpi* Sykes[2] that clings almost scale-like to submerged stones and dead leaves in water.

In collecting aquatic insects for live study it is often sufficient to bring them to the home or laboratory in water-soaked green algae, decayed leaves or moss. In such media they will be less likely to attack one another than in a jar of water only. The larvae and pupae of Chironomidae are best transported in open containers with water supplied with algae. These insects require well aerated water.

The aquarium in which organisms are to be studied, or a stock kept, may range from a small dish to a vessel holding many gallons. Comparatively shallow containers with vertical sides are more generally suitable. As far as possible natural conditions should be simulated, the object being to satisfy the inmates of the vessel rather than the spectators. The goldfish bowl complex

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[1] The alimentary tracts of three specimens of a goby collected in streams behind Honolulu were examined, with results as follows:

Goby No. 1. From Hering Valley, Makiki, elevation about 1,000 feet, May, 1933. Length, 5 11/16 inches.
Mollusca: many quite small *Lymnaea*-like snails, 1 *Ancylus sharpi* Sykes. Crustacea: 1 Ostracoda, many Copepoda. Insecta: Diptera; a few nematocerous larvae including 1 limnobiid, *Tanytarsus,* and 2 *Tanytarsus* pupae; Odonata, 1 small *Megalagrion* nymph and remains of others; Thysanoptera, 1 thrips. Arachnida: 3 mites. In addition, much undetermined fine organic matter, the waffle-like squares of diatomaceous plants, filamentous green algae and some stellate leaf hairs.

Goby No. 2. Same locality and date as No. 1. Length about 2 10/16 inches.
Insecta: Diptera; Chironomidae; a considerable number of larvae of *Tanytarsus.* Much undetermined fine organic matter. The bulk of the recognizable material consisted of waffle-like Diatomaceae.

Goby No. 3. Upper Manoa Valley, January 26, 1936. Length about 7 inches.
Crustacea: Portions of one or more Isopoda, moulted (?) portions of the *Atya* shrimp. Myriapoda: A small milliped (*Aporodesminus,* probably *wallacei* Silvestri). Arachnida: 1 mite. Insecta: 1 limnobiid larva; Odonata, 1 nymph of *Megalagrion oceanicum*; Coleoptera, 1 scolytid. In addition was much fine unidentified material and a few fragments of moss.

This interesting though somewhat homely fish is well worth studying. The aquarium, however, must be screened over to prevent it from jumping out. It has the curious habit of burying itself with great rapidity in the sand or mud at the bottom of the pool or tank and frequently conceals itself in narrow spaces in or between boulders.

[2] Determined by Dr. C. Montague Cooke, Jr., malacologist at the Bishop Museum, Honolulu.

should therefore be avoided. A few pebbles or stones, of which several are not completely submerged, will prove useful, while for plants, the common *honohono, Commelina nudiflora,* is very satisfactory. A length of this plant stem curved into a shallow dish, or a quantity placed in a large aquarium, will root out at the joints and for a time grow quickly. The neat little *Pilea peploides* Hook. & Arn. (*Urticaceae*)*, found dipping its roots from rocks in mountain streams, is a plant worth trying. Green algae such as the abundant *Cladophora* while perhaps rather untidy in effect, are useful aerators and also furnish retreats and in some cases food, for smaller water insects. Such algae may be restricted to one side of the container, the other remaining as more open water.

Semi-aquatic insects should be treated as such—they are likely to drown in steep-sided containers with water only. Plenty of debris, algae, dead leaves and a little soil may be required. Do not allow oily films to gather on the water. Aquaria should be covered with a fine screen or netting rather than with glass. Plenty of good air is often essential.

What insects get along together and what ones do not, will form an instructive experience for the beginner in the study of water-loving organisms. Many species will prove highly carnivorous and must therefore be isolated. In studying life-histories—moult-skin counts, food habits, etc.—the subject had best be placed in as small a container as is consistent with its well being, a petrie dish often serving this purpose. Thus exuviae will not be lost nor will the insect be able to conceal itself too effectively. Microorganisms such as Protozoa and the tiny Crustacea common in sunlit stagnant waters will give many young aquatic carnivorous larvae a start in life so that increasing in size, these insects will soon be large enough to feed upon bloodworms (*Chironomus hawaiiensis*) that may be found in reservoirs, leak pools, ditches, etc. The eggs of *Chironomus* are attached as short, thick gelatinous strings to stones, surface weeds, debris, etc., just beneath the surface of the water. Mosquito larvae are good food for aquatics, but they are, generally speaking, rather too agile for their capture, so that some escaping their enemies, will mature and constitute a nuisance. Finally, for larger insects, such as a third-stage *Rhantus* beetle larvae and the adult beetles themselves, and the nymphs of

* Identified by E. L. Caum.

Anax dragonflies, the tadpole of the rough-skinned little *Rana rugosa* frog will serve well. Worms, sowbugs (Crustacea), etc., may also be fed them. All food remains should be removed from the container.

Certain aquatic insects like the Odonata or dragonflies are capable of prolonged fasts, but the larvae of dytiscid beetles like *Rhantus,* being almost constantly active, cannot under normal conditions long abstain from food.

Aquatic beetle larvae generally pupate in moist soil; it is essential therefore that some sort of sloping bank of mud be made accessible to the larva, and a flattish pebble placed in an advantageous position on this little bank may be an inducement for the insect to enter the soil at that point. Or, a shallow dish of water may be sunk to its rim level in wet soil contained in a wider, taller dish and connection established between the two by means of limp weeds, algae, twigs, etc. Our dragonflies and damselflies creep up a steep bank, a boulder, plant or twig, for the final transformations; hence a steeply sloping twig, bit of wood or screen, etc., should be made to project from the water for at least a foot so that the emerging insect will readily locate it and crawl up its underside.

The eggs of many aquatic and subaquatic insects have shells of considerable transparency and provide, even without dissection or the use of stains, excellent if unrefined studies in embryology, while the larval stages, particularly the earlier ones, frequently show the tracheal, or respiratory system to great advantage, with the alimentary canal, the circulatory system, and the imaginal discs (wing buds etc.) often quite clearly outlined.

PART I. ORDER COLEOPTERA (BEETLES)

There are 7 species of aquatic or semi-aquatic beetles in the Hawaiian Islands. The Dytiscidae or "diving beetles" with thread-like or bead-like antennae are represented by 3 species, of which 2 are apparently endemic. The adults swim mainly with simultaneous or rowing strokes of opposing legs. The Hydrophilidae with the antennae somewhat clubbed and the maxillary palpi relatively long, number 4 species that are aquatic. They swim less strongly than the Dytiscidae and with an alternate or running movement of the legs. There are in addition here several land-inhabiting Hydrophilidae.

FAMILY **DYTISCIDAE**

Rhantus pacificus (Boisduval).

Colymbetes pacificus Boisduval, Voyage of the Astrolabe, Col. 1, p. 50, 1835.

Rhantus pacificus, Sharp, Tr. Dublin Soc., (2) II, p. 607, 1882.

This is our largest, most active and most aquatic water beetle (Plate II, 1). It is oval in form, and ranges from about 10 to 12.5 millimeters, or half an inch long. The general shade in pinned specimens is blackish, although when in the water a brown and coppery lustre may become evident. There is a pale area on top of the head, the sides of the thorax and the antennae and legs are, more or less, light brownish, while the wing covers are flecked, particularly outwardly, with pale brown. The male is readily distinguished from the female because it only, has a widened area of sucker-like discs on the underside of the tarsi of the first and second pairs of legs (Plate II, 8).

Rhantus pacificus is common in mountain streams. Small headwater pools deeply entrenched between banks and connected one with the other, often by scarcely more than a trickle of water, are a favorite resort of this beetle. On the island of Oahu it occurs as high as 3,500 ft., i.e., in a small spring on the slopes of Mt. Kaala, Waianae Range. This is, perhaps, the most elevated permanent water on the island. We have found it also really abundant nearly a mile high in a forest on the eastern slopes of Mauna Kea, Hawaii, dwelling in the clear cool water of little creeks, or in boggy pools along the more open trails there. On the other hand, it does not scorn rain puddles close to the seashore. On December 29, 1931, one such body of water, then in extent about 5 feet long, 2½ feet wide and not more than 3 or 4 inches deep, alongside a roadway on the island of Molokai, was found to contain, in addition to numerous "bloodworms" (the larva of the midge fly *Chironomus hawaiiensis*), hordes of small nymphs of the dragonfly, *Pantala flavescens* and a number of *Rhantus* larvae, mostly well grown. It was quite evident that in this shrinking puddle the struggle for existence was waxing more and more severe, the stronger organisms devouring the weaker. The clearest of waters or the most muddy appear to serve equally well. Near Ewa, Oahu, several *Rhantus*

larvae were found thriving in storm-water pools so reddishly muddy as to render these larvae as well as other organisms quite invisible except when right at the surface.

Occasionally one sees several of these insects propelling themselves in graceful curves near the surface of the water, with oar-like strokes of the stout, hair-fringed hind legs, exploring the bottom or resting, in seeming content at the surface, the posterior extremity of the body exposed to the air, the swimming legs curved jauntily upwards. Or, if the beetle is in a wary mood it shoots up from the depths of the pool, touches the surface for the fraction of a second and then darts down to shelter, a clinging air-silvered bubble marking its descent. A heavy footfall, or a stone cast into the water, and the beetle may vanish into the depth, reappearing in good time, for a moment, to replenish its air supply.

When taken out of water it runs rather quickly and finally flies away. It is also able to take wing from the vertical sides of a glass vessel, up which it has climbed with the aid of the surface tension of water.

With but trifling care it can be kept for a long while in captivity; one female specimen captured as an adult and fed at irregular, and sometimes rather long-spaced intervals, survived a little over eight months. In its native state it probably feeds on whatever suitable little invertebrates fall into the water, and it also devours aquatic forms. It has been observed consuming *Philoscia angusticauda* Budde-Lund, a common sowbug that is found near water and in other damp situations, and an examination of the crop contents of one of these beetles from a pool in Kamokuiki Valley, Waianae Mts., Oahu, disclosed remains, including entire legs and an antenna, of an amphipod crustacean, probably a species of *Orchestia*. Perkins (Fauna Hawaiiensis, Introduction, p. clxxviii, 1913) records it as feeding upon young nymphs of *Agrion oceanicum* McLachl., one of our larger damselflies (Odonata). It is often found in pools containing other species of damselflies. A bather on the Island of Kauai complained of having been bitten by these insects when he immersed himself in a cool mountain pool.

I was accustomed to feed some *Rhantus* beetles, confined in an aquarium, with disabled cockroaches, grasshoppers, and I even gave them a crippled centipede, and it soon became evident that they locate food more through the sense of taste or smell, than by

sight. A wounded cockroach is cast upon the water. Except for its weak struggles, there is no other movement in the aquarium. Presently, however, one of the beetles, in need of air, rises from the bottom; it catches the diffused taint of the bleeding insect and swims about near the surface. It may thus pass within an inch of the cockroach but apparently does not see it, and some moments elapse before its prey is located, into the wounded portion of which it now bites hungrily. In the meantime, other *Rhantus* bestir themselves; they swim about in an enquiring manner, and at last all are struggling to get a firm hold upon the cockroach.

As long as small fish and shrimps have plenty of space, as was the case in the aquarium, they will most likely long evade the beetles; in cramped quarters, however, *Rhantus* may successfully attack top minnows (*Gambusia*). Once a large flatworm (*Bipalium kewense* Mos.) was placed in a pool containing these beetles. Twice, one of these beetles made as if to seize and bite this slimy creature, but in the end rejected it as an unsavory morsel. Earthworms however often fall into steep pools and are then eaten by *Rhantus*.

The first two pairs of legs are fitted for grasping, though they may also take some part in locomotion. By their aid the prey is held and, if the beetle—more buoyant than water—has not wedged itself under some stone or other object, it clings to something with these four feet in order to remain under water.

The eggs of *Rhantus* are whitish, delicate and rather elongate, with the end from which the larva hatches, more broadly rounded. They measure nearly two millimeters in length. In pools, they were found glued singly to the stems and the hair-like rootlets of the moisture-loving plant *honohono* (*Commelina nudiflora* Linn.) (Plate II, 2), to filamentous green algae, to dead and partly rolled up floating leaves and to other objects immersed in water.[1] In the laboratory the eggs were also fastened to the sides of a glass dish. Few appear to be deposited at one time; a captive beetle laid 13 eggs within a week, and most of these within 2 or 3 days. As the

[1] In Guatemala the writer found that dytiscid beetles oviposited in the frothy egg-masses of an amphibian, presumably a tree toad. These egg masses adhered to objects in rain puddles, or along the margin of the latter. In this manner the beetle larva is assured an abundance of food that will enable it to complete its transformations in a fair proportion of these often very temporary puddles. Some of these beetle larvae were sent to the Bureau of Entomology, United States Department of Agriculture, and there determined as belonging to two species, of which one was a *Rhantus* The larvae readily devoured the young tadpoles.

eggs develop, the blackish eyes of the enclosed larva appear through the diaphanous shell, and a dark streak along its sides marks the position of the longitudinal air tubes. In about 3½ days the curved larva ruptures the shell. It now straightens out and is a good deal longer than the egg shell, the head is dark and well armored, and each segment of the body above bears a dark plate, of which however, the tailmost one forms a complete ring; just beyond this ring, on the upper side, are situated the paired air-tube openings for breathing, and immediately below these openings, the two slender processes or cerci arise. The underside of the larva then, with the exception of the head and terminal ring-like segment, is rather soft, and pale, and so also, when this active and voracious creature is well filled out with eating, are the spaces between the plates.

Though never attaining the speed of the adult beetle in the water, it is nevertheless a capable swimmer and, with quick oar-like strokes of its three pairs of hair-fringed legs, aided by occasionally flexing the body, travels gracefully and rather swiftly through the water. When quite young the larvae seem to favor the surface

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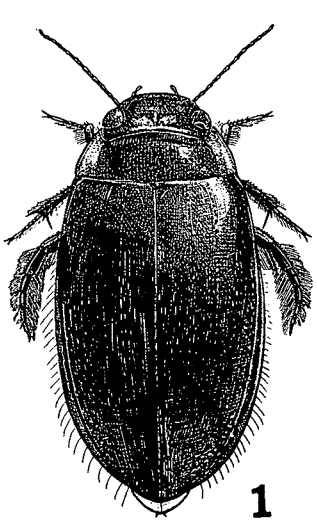
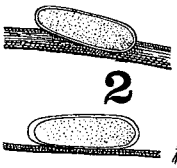
II

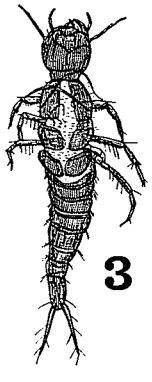
RHANTUS PACIFICUS

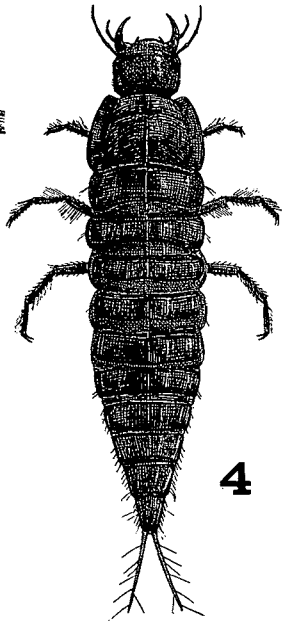
Explanation of Plate

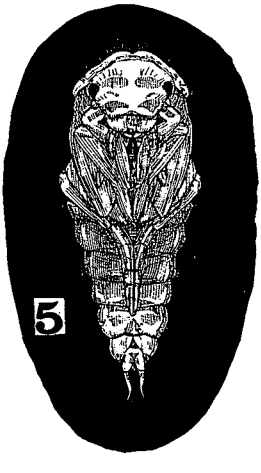
1. Adult beetle, female. Length 11 millimeters.
2. Eggs glued to immersed plant rootlets. Length about 1.85 mm.
3. Moult skin of young larva.
4. Full grown larva. Length about 14 mm.
5. Pupa, from underside. Length about 9 mm.
6. Head of last-stage larva, from above: A, eyes; B, antenna; C. mandible; D, maxilla (=base and inner small 2-jointed appendage) and 4-jointed maxillary palp; E. labium and labial palpi.
7. Mandible detached; to show canal on inner side, black indicating its opening to the exterior, stippled shading the canal itself.
8. Fore tarsus of adult male, to show the numerous sucker discs, from beneath.
9. Head of adult beetle, female, from beneath: A, compound eye; B, antennae; C, mandible; D, maxilla (l, innner with comb=lacinia; g, intermediate palpiform=galea; mx.p, outer=maxillary palpus); E. labium (m, mentum; li, ligula; gm, gulamentum; lp, labial palpus); F, labrum. The labrum with the inner epipharynx is on the upper side of the mouth or buccal cavity; the labium is on the lower side.

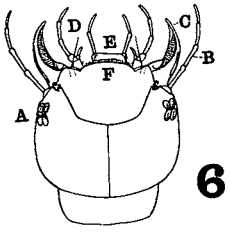


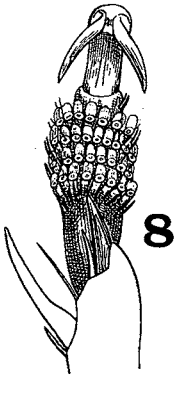


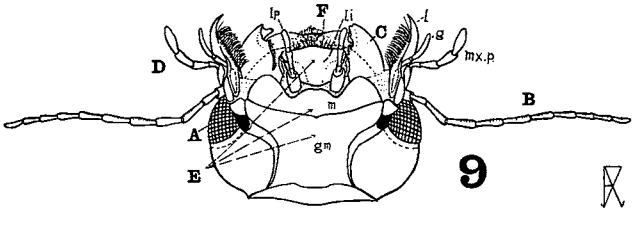












Rhantus pacificus

region of the water, but the larger and more vigorous ones dive easily to the bottom of pools of some depth and explore the sides and the weeds for prey. In getting air into the air tubes which open at the base of the paired tail-like processes, the *Rhantus* larva rising to the surface, floats obliquely head downwards, jaws agape and the legs hanging freely—all lending to the appearance of relaxation. It is somewhat lighter than water, for it has capacious air reservoirs formed by the enlarging of the longitudinal air tubes. A small experiment with one of these larvae, well grown, showed that it was capable of enduring (though with obviously increasing discomfort) a submergence of at least three hours.

The mouth-parts and the method of feeding of the larvae of certain types of Dytiscidae—to which family *Rhantus* belongs—have been studied by a number of observers. The mandibles of the *Rhantus* larva (Plate II, 6C, and 7) are rather slender and curved, in strong contrast to the stout toothed jaws of the adult beetle (Plate II, 9C) and, in addition, they are deeply channelled on their inner side (Fig. 7), the channel opening rather widely near the tip and the base of the mandible and is nearly closed, slit-like, by the approximation of the two margins, in between. This is the structure in all the larval stages. In feeding, the beetle larva holds its prey in closed jaws, presumably injects a digestive fluid into its body, and then sucks out the juices.[2] When the jaws are thus closed, or nearly so, over the perforated victim, the basal opening of each channel connects with the mouth, and thus, through the partly transparent chitin there, one may see the fluid pass at intervals with great rapidity, from the base of the jaws on either side, across to the central gullet. The food habits were observed chiefly in the laboratory, where the larvae were often fed with the aid of forceps. They greedily sucked the juices of small soft insects, such as caterpillars and mosquito wrigglers, but were not always adept at capturing the latter. A *Rhantus* larva in its last stage of growth would dispose of a half dozen large mosquito larvae of an evening. It likes to feed at ease with its tail-end at the surface. When it has sufficiently sucked out the juices of its victim, the more or less chewed and shrunken remains are let fall. Except sometimes to a

[2] My few dissections of adult and larval *Rhantus* have shown that, in keeping with the nature of their respective mouthparts, the adult beetle often swallows relatively large portions of its prey, while the larva ingests only the body fluids or quite minute, more or less solid particles. Furthermore, the larva lacks the conspicous, heavily chitinized gizzard of the adult, showing that it has little need for a straining and crushing apparatus.

slight extent, it does not employ its legs in holding its prey in position, its strong curved jaws amply sufficing.

In a pool behind the peak of Tantalus (Puu Lehua) a small *Rhantus* larva was observed eating a mosquito wriggler, of which there were many in this little body of water. In the same locality on March 13, 1932, and more than a week after heavy rains, a quantity of an amphipod crustacean, *Orchestia* sp., an arched leaping creature with a compressed body and very common under wet leaves and other debris, were found dead, decaying and discolored orange red, at the bottom of a pool where two small *Rhantus* larvae were each attacking a corpse. On several occasions large *Rhantus* larvae were seen devouring *Philoscia angusticauda* (Isopoda), an abundant sowbug crustacean that frequents the margins of pools and often drowns in them. Cannibalism was noted among *Rhantus* larvae in their natural haunts and this trait is emphasized in captivity.

The larva sheds its skin twice during its active life, and thus there are three *larval* stages. The first of these moults takes place about two days after hatching from the egg. The skin splits along the pale line of least resistance in the middle of the thorax, and along the top and sides of the head, and it is cast off in its entirety (Plate II, 3), so that this discarded garment really looks a good deal like a limp larva. Immediately after the moult, the *Rhantus* larva is pale, glassy and whitish, the eyes dark, the mandibles red at their tips, the gut in part colored, and the longitudinal breathing tubes are each marked off in a broad dark stripe. But the larva soon darkens into a sort of brownish gray, and resumes its voracious activity. It moults again about three days later, when it is 8 millimeters or more in length. The color may again be a sort of sandy brown, or the head and plates may be almost black. It eats actively for a few days, and attains a length of perhaps 15 millimeters (Plate II, 4) and assumes a more or less yellowish tinge beneath. Now it refuses food, often swims about restlessly, and finally crawls up the muddy bank of its prison seeking a hole or cranny, and at last burrows under a pebble, or simply, into the mud, to a depth perhaps of less than an inch and, with the aid of its head, forms a neat, smooth, short-oval chamber. In this chamber it rests on its back, in a curved position and, in a few days the skin splits and discloses a delicate, creamy, yellowish-white pupa

(Plate II, 5) with glass-like appendages, dark eyes, a pair of slender spines at the tip of the body, and fine erect stiff, reddish brown hair, chiefly on the back, that raise it clear of the floor of the shining, damp pupal chamber. It is very sensitive and wiggles actively if disturbed. In a few days more the beetle sheds the pupal envelop. At first it is pale and delicate; so it does not dig its way out of the cell to seek water until it is strong, hardened, and dark colored.

But a single *Rhantus* was reared from egg to adult stage, as follows:

Egg laid about August 6.
Egg hatched about August 10.
First larval moult August 12 or 13.
Second larval moult August 15.
Entered soil to pupate August 28.
Adult disclosed September 4.
Or, about 4 weeks from egg to adult.

In nature, particularly in the highlands, the cycle is probably longer, but at least up to an altitude of about 1,500 feet, there seems to be no, or hardly any resting period from development, for adults and larvae may be seen throughout the year there. In the lowlands, this beetle occurs in some of the rain or storm puddles often passing through a generation or two in them.

This beetle appears to be found only in the Hawaiian Islands. It belongs to a genus of world-wide distribution that is represented by dozens of species. Among these species in other Pacific islands, are *Rhantus liopteroides* Zimmermann, *Rhantus pulverosus* Stephen, and *Rhantus annectens* Sharp, all from Samoa, and *Rhantus debilis* Sharp from Tahiti.

Copelatus (Liopterus) parvulus (Boisduval).

Colymbetes parvulus Boisduval, Voyage of the Astrolabe, Col. I, p. 50, 1835.

Copelatus parvulus, Sharp, Tr. Dublin Soc. (2), II, p. 568, 1880-1882.

Copelatus mauiensis Blackburn, Tr. Dublin Soc. (2), III, p. 120, 1884.

Liopterus parvulus, Zimmermann, Coleopterorum Catalogus (W. Junk), Pt. 71, p. 145, 1920.

This little reddish brown to blackish beetle of slender parallel form and usually between 4 and 5 millimeters in length (Plate III, 10) inhabits small, generally clear pools sheltered in the gullies of the fore-hills and ranges thence to waters in the cool uplands at an altitude of 2,000 feet, or more. It is frequently found in company with *Rhantus,* its large sturdy relative, and with *Limnoxenus,* the squeaking hydrophylid beetle. And often it dwells in tiny water pockets of an intermittent character, of which some dry up entirely while others, situated in cooler regions of considerable rainfall, may shelter beneath moist pebbles in waterless basins lined with rather hard mud, *Copelatus* beetles that await the next flood to resume activities.

Under water this restless insect reflects a rich coppery brown color, as it swims about gracefully, as a rule, hugging sides and bottom—which makes it rather difficult to capture—and occasionally rising to thrust out the tip of its abdomen for air. Both adult and larva may be taken on submerged stones when these are suddenly lifted out of water.

Of carnivorous habit, the adult beetle will readily feed upon dead insects and in the field was once found devouring a larva of its own species. Dissection of the foregut (crop and gizzard) of 9 adult *Copelatus* secured from one pool in the headwaters of Pauoa Stream, back of Honolulu, late on the morning of May 14, 1933, revealed that much, if not most of its food supply consists of the tiny copepod Crustacea that abound in the beetle's habitat and that swim in swift jerks or dart in a similar manner along the surface of submerged stones or debris. Of these 9 foreguts examined, 3 contained remains identified as those of Copepoda, 1 the remains of a small fly larva as well as unidentifiable material, 2 had undetermined insect remains, while the last three were practically empty. None of these guts contained much food, so it is clear that in order to survive the beetle must be an active forager. Food materials that had passed beyond the well chitinized gizzard were in small, unrecognizable particles. Tiny floating bits of sweet chocolate when floated on a highland pool, proved quite attractive to the beetle and to certain dolichopodid flies. The male *Copelatus* beetle has but 6 discs on the underside of the fore and intermediate tarsi (Plate III, 13)—compare this condition with the more than 30 discs in the male *Rhantus* beetle.

Several eggs were laid by captive females. They were whitish, rather stout, slightly oval and about 0.8 millimeters long. They were fastened lengthwise along the muddy bottom of the vial of water in which the beetles were confined. (Plate III, 12A) illustrates an egg in a sort of envelope to which adhere fine particles of debris, Fig. 12B shows an egg lacking this envelope. None of the eggs hatched.

After some speculation regarding the larval habits of this beetle and a considerable search, the pale straw brown larva was discovered. Whereas the larva of *Rhantus,* its large relative, is an accomplished swimmer, sooner or later to be discovered in the pool as it forages about freely or boldly rises to the surface for a supply of air, the *Copelatus* larva (Plate III, 11) has relatively secretive habits. Although of much the same graceful form as the *Rhantus* larva, its legs are unfitted for swimming since they lack the fringe of fine hairs present in the larva of *Rhantus. Copelatus* therefore, creeps about on partly submerged stones, leaves, immersed tufts of rootlets or other objects, being able then to easily take in air at its tail end and also to seek its prey which, judging from dissections of a few larval foreguts, consists of the minute copepod Crustacea that are so abundant on submerged objects or swimming freely. Of 6 *Copelatus* larvae secured from small pools behind the Peak of Tantalus (Puu Lehua) in April 1933, the foreguts of 3, or possibly of 4, showed remains of Copepoda, while a 5th one contained a single valve or shell of a small ostracod crustacean. None of this material had passed beyond the gizzard, which consists of one large and two small spiniferous pieces of chitin, the

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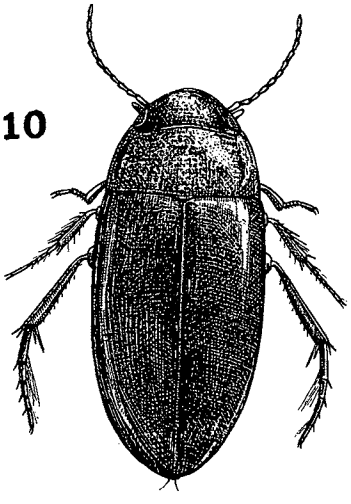
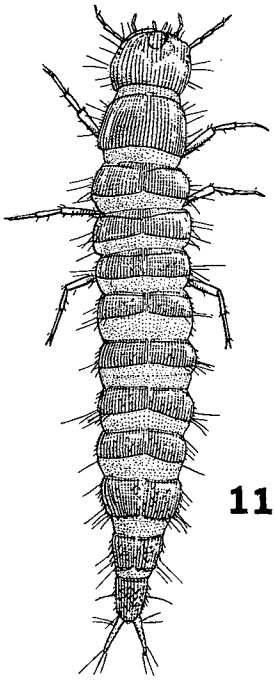
III

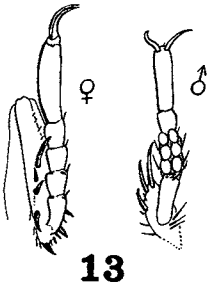
COPELATUS PARVULUS

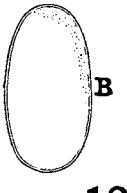
Explanation of Plate

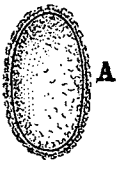
10. Adult beetle, length 4.8 mm.
11. Larva, last stage, length 6.75 mm.
12. A, egg with envelope, length 0.8 mm.; B, egg without envelope.
13. Foretarsus of adult beetle, female without, male with sucker discs. Tarsus of female a little inclined from underside, of male directly from underside.
14. A. larval mandible, from above; B, larval antenna; C. larval maxilla and palpus.
15. Pupa, length 4.3 mm.

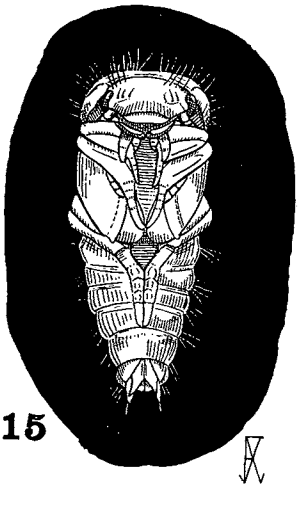


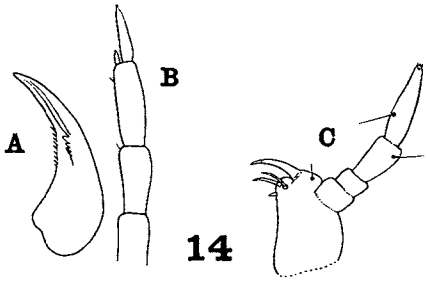












Copelatus parvulus

large piece being of subconic form. Since the *Copelatus* larva ingests food in a solid state, sometimes swallowing almost or quite entire, its small crustacean prey, a chitinized gizzard is to be expected. In the possession of this rather well developed organ it differs from the larva of our two other dytiscid beetles that suck the juices of their prey or at most, swallow only minute particles of more or less solid matter. In further keeping with its feeding habits, the mandibles of *Copelatus* are not deeply channeled out but have sharp bladelike edges and rows of fine teeth (Plate III, 14, A), while the maxillae (Plate III, 14, C) are rather stout and bear several strong spines on their inner side. Aside from the few dissections of alimentary tracts, the feeding habits of the larva were not studied.

This insect was not reared from egg to adult, but field collections of larvae indicate that there are three larval stages; the larva quite pale at first becoming somewhat darker at each stage and moulting for the third time to form a pupa. Although unable to swim, the larva can run about actively and may remain entirely submerged without any apparent inconvenience for an hour or more. As in other aquatic insects, colonies of the long-stemmed protozoan, *Vorticella* may sometimes be found attached to its body. A larva that was apparently full grown (Plate III, 11) measured nearly 7 millimeters in length of body. Its dorsal plates were roughened with fine tubercles that, towards the posterior end of the body were developed into short spines. This larva having been once disturbed from the little mud bank of its prison, again dug into the mud and, employing its head as a sort of ram, formed a smooth-walled subspherical cell that for a time was open above but which was finally closed by pushing mud in place with its head. In due time the very sensitive resting larva transformed into an equally sensitive pupa between 4 and 5 millimeters long, of a glassy creamy white color except for the dark eyes, and with erect hairs on the sides and back (Plate III, 15). The pupal stage is brief.

This beetle occurs in the adult state the year around. Thus far it has been reported from only the Hawaiian Islands, having been taken on Kauai, Oahu, Maui, Molokai and Lanai. It belongs to a genus of nearly 200 species, as listed by A. Zimmermann, in Coleopterorum Catalogus, Pars I, 1920, and of which 27 species are placed in the subgenus *Liopterus* of Aubé (1836).

Of interesting habitat is *Copelatus pandanorum* Scott of the Seychelles, and of which its discoverer and describer says in part (Trans. Linn. Soc. London, ser. 2, Zool. Vol. XV, pt. 2, Sept. 1912, p. 259): "The habitat of this species is very remarkable. The series before me consists of 17 males and 20 females, all of which without exception were found living in the water that collects between the bases of the leaves of certain precinctive species of screw-pine (*Pandanus*), many feet above the ground. They were found only in the endemic high damp mountain forests, in situations where the water between the leaves would never under ordinary circumstances dry up. In one case two larvae, having a quite characteristic Dytiscid facies, were also found between the leaves, showing that in all probability the whole life-cycle takes place in this curious habitat."

In the water and humus between the leaf bases of a bromeliaceous plant in the mountains of Trinidad, British West Indies, Scott discovered *Aglymbus bromeliarum* Scott, a water beetle allied to *Copelatus,* and says that "The *Aglymbus* is more flattened dorso-ventrally than its congeners, this being perhaps an adaptation for living in the narrow spaces between the leaf-bases (*Copelatus pandanorum* is also flattened)." (Ann. and Mag. Nat. Hist., Ser. 8, vol. X, 1912, pp. 424-438, 1 pl.)

Hydrovatus confertus Sharp.

Hydrovatus confertus Sharp, D. On Aquatic Carnivorous Coleoptera, p. 329, 1880-1882.

In certain weedy lowland swamps, in abandoned rice fields, in hoof prints of cattle and in other small water pockets by taro patches, particularly where fish have not yet penetrated, and Protozoa, rotifers, minute Crustacea and other diminutive organisms abound, an obese little water beetle (Plate IV, 16) some 2.5 millimeters long and of a variegated brown color may frequently be found.[3] Its often restless behavior suggests impatience as it swims for a short distance along the bottom, pauses a moment, and is off again. Occasionally it rises to the surface where, assuming an almost vertical position takes in a supply of air at the tip of its

[3] It may also occur in the shelter of filamentous green algae in taro patches that contain fish; and while mainly a lowland insect it dwells, with two larger water beetles, *Rhantus* and *Limnoxenus,* in certain tiny stagnant pools in boggy Palolo crater situated at about 1,400 ft. elevation in the mountains behind Honolulu.

pointed abdomen, and then usually descends immediately. Appearing scarcely larger than some of the tiny bivalve crustaceans that share its environment, this chubby little insect swims at a steady pace, not in lunges, as do some of the larger dytiscid beetles. In captivity we usually see it half running, half swimming—with pauses—up and down the sides of the glass jar, and we take note that the well-fringed first and second pairs of legs, but chiefly the second pair function most in propulsion, the slender third pair trailing behind or partaking in lesser movements, although actively operating when the beetle is swimming freely. Individuals will live for many months in an open dish half filled with water, to which some filamentous green algae, debris, and occasional food such as dead insects have been added, and the fact that the dish remains uncovered seems not generally to tempt them to fly away. The beetle does not appear to be very aggressively carnivorous; large mosquito wrigglers that share little water pockets with it seemed unmolested. Dissection of the crop and gizzard of a few of these beetles revealed some food remains capable of identification and some that was quite unrecognizable. Two of the beetle crops contained what appeared to be head-portions of the larva of a moth fly (Psychodidae); a third held fragments suggesting a tiny crustacean, while a fourth disclosed the curious bristles, or chaetae of a nereid, a worm sometimes occurring in fresh-water marshes close to the sea, but with the great majority of species characteristic of salt water. In the crop of a *Hydrovatus* beetle a few days in cap-

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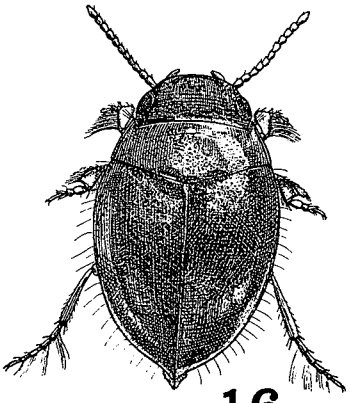
IV

HYDROVATUS CONFERTUS (16-23)
COELOSTOMA FABRICII (24)

Explanation of Plate

16. *Hydrovatus confertus,* adult beetle. Length 2.55 mm.
17. Egg. Length 0.6 mm.
18. Young larva. Length—nose to tip of middle tail process—1.33 mm.
19. Large larva. Tail to show the two entering tracheae.
20. Large larva. Head, from beneath.
21. Adult. Crop, gizzard and part of gastric coeca. To show a copepod crustacean in the crop. Laboratory-fed beetle.
22. Adult male. Fore tarsus, from side to show two of the pads of the basal joint.
23. Large larva. Head, from the side.
24. *Coelostoma fabricii,* adult beetle. Length 6 mm.



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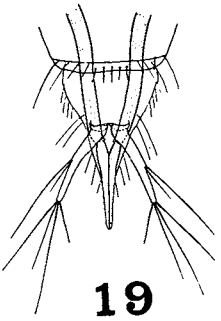

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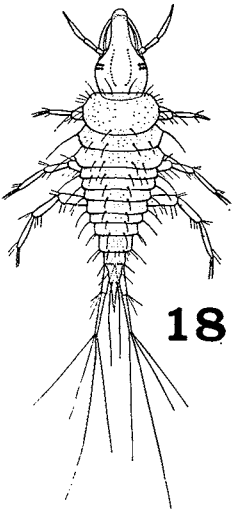

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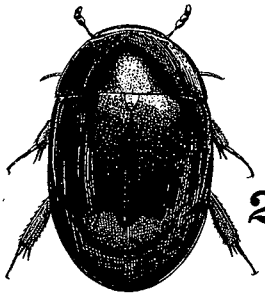

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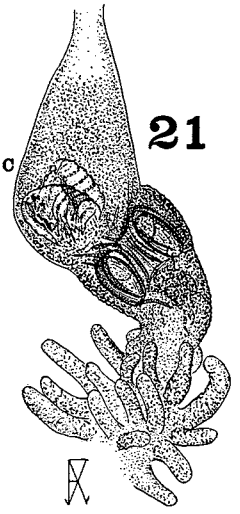

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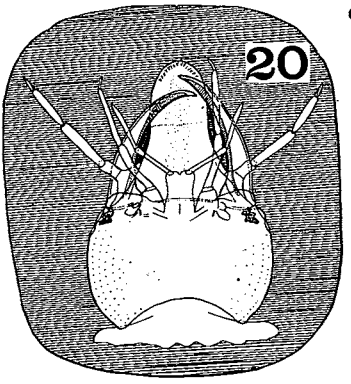

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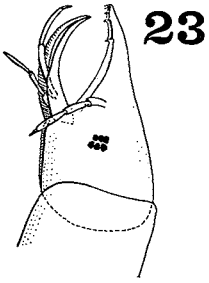

23

Hydrovatus confertus and **Coelostoma fabricii**

tivity was found a copepod crustacean that had been swallowed practically entire (Plate IV, 21, C). Such tiny darting Copepoda may be very abundant where the beetle lives. In its rummaging about for food it appears that the sense of taste or smell plays a much greater part than that of vision.

The egg of *Hydrovatus* is slightly curved oval and about 0.6 mm. long (Plate IV, 17). One was found weakly glued to algae in the jar-aquarium. It hatches into a very curious, rather spindle-shaped larva (Plate IV, 18) with a snout-like process against which the tips of the mandibles meet (Plate IV, 20 and 23). Looked at under the microscope this nosey little organism might well remind one of a dolphin (Cetacea), with its prominent strongly-toothed beak. For all its diminutive size it is a savage-looking creature as it runs lightly over the flocculent bottom or clings to a bit of plant near the surface, the long sickle-like mandibles agape beneath the great toothed snout-like process. Though traveling easily and gracefully under water it is unable to swim and so must creep to the surface for air, which it takes in at the sharp tail-like process into which the two longitudinal tracheae extend (Fig. 19). It may of its own accord stay under water for half an hour. In captivity the larva was fed on soft crushed insects, and living Ostracoda and Copepoda. When a quantity of *Cipridopsis* (Ostracoda), curious swimming little clam-like creatures, was placed in the *Hydrovatus* dish some of the beetle larvae soon caught one in their jaws; Copepoda however, with their darting speed were less frequently captured and I saw but one in the jaws of a *Hydrovatus* larva.

Probably the larva of *Hydrovatus* has three stages. Plate IV, 18, shows a very young larva 1.3 mm. long to the extremity of the two processes on each side of the tail. This is probably a first-stage larva. Compare its caudal portion with that in Plate IV, 19 (probably in the last larval stage). A large larva is a sort of pale brownish with dark specks, the alimentary tract showing darkly through. There is a group of six little eyes on each side of the head. Very small larvae may be almost transparent.

Hydrovatus confertus often inhabits the same waters as the small *Enochrus nebulosus* and the larger black *Coelostoma fabricii,* and I believe that the sturdy larvae of these two hydrophilids are frequently predacious upon its young.

This insect was first taken here by F. W. Terry who collected it in Honolulu on June 12, 1904. It has been taken also at Olaa, Hawaii, on April 19, 1920 by O. H. Swezey. It is an oriental species and belongs to a large genus. It is common on the lowlands of Oahu.

FAMILY **HYDROPHILIDAE**

Limnoxenus semicylindricus (Eschscholtz).

Hydrophilus semicylindricus Eschscholtz, Entomologist, p. 42, 1822.

Hydrobius semicylindricus, Sharp, Trans. Entom. Soc. London, pp. 82-83, 1879.

Limnoxenus semicylindricus, Knisch, Coleopterorum Catalogus (W. Junk), Pars 79, Hydrophilidae, p. 175, 1924.

If we were to explore even the smallest of our mountain streams for aquatic insects, it is likely that, upon turning over a partly submerged stone, or in searching the underwater banks and the bottoms of pools, we would find a convex, rather long-oval, dark shining beetle, blackish, olive green or even purplish—according to light or age—some 8 or 9 millimeters or about a third of an inch long. Detached pools are to its liking, and it lives in mountain bogs and in such little bodies of water as are choked with green algae, among the mass of which its firmly attached egg-cases may be found. It even frequents dripping-wet mossy or weedy banks above water. Once in a shaded canyon on the Island of Molokai two of these beetles were found in a shallow and somewhat stagnant quart of water in a hollow atop a boulder in a dry stream bed. The highest point at which I have yet taken this beetle is at the Gunnera-plant (*ape ape*) spring on Mt. Kaala, Oahu, at about 3,600 ft. elevation. It occurs also near sea level.

Sooner or later we might hear an underwater noise, like a protesting squeak that is produced by this insect and that is audible from a distance of two or three feet.[4]

[4] The sound-producing organ has recently been studied by Dr. O. Marcu (Zoologischer Anzeiger, Nr. 3/4, Band 100, Sept. 15, pp. 80-81, 1 Fig., 1932) in *Hydrophilus* and *Hydrobius,* the latter genus being closely related to *Limnoxenus.* In *Hydrophilus* and *Hydrobius* there is a finely cross-ridged area on the edge of the second abdominal segment, and this Marcu terms the "pars stridens", while on the underside of the wing covers and near their outer edge is a field thickly beset with fine chitinous elevations, the "plektrum". Stridulation is effected by rubbing one opposed area against the other, the necessary movement being secured probably by expansion and contraction of the abdomen. In *Limnoxenus semicylindricus* these areas are apparently quite similar to the above, the abdominal area or "pars stridens" is situated on the side piece or pleurite of the third abdominal segment. It is not a very obvious apparatus.

Like other hydrophilid beetles, *Limnoxenus* swims with alternate strokes of its rather slender legs, of which the tarsi of the second and third pairs are strongly hair-fringed on one side, the fore tarsi being weakly fringed. The locomotion is somewhat wavering and quite inferior to that of the dytiscid beetle, *Rhantus* and others, and, because of the immense spreading air bubble that often silvers the underside except the head, and renders it very buoyant, the beetle may be unable to swim to the bottom but must creep downwards among algae, weeds or other submerged objects. When at rest underwater it may be readily captured with the fingers.

On account of the comparatively small size and quick movements of *Limnoxenus,* it is not easy to see just how it takes in a supply of air; the process has been well studied by observers particularly in species of the genus *Hydrous,* and it appears to be essentially the same in these, its giant relatives. When *Limnoxenus* needs a fresh air supply, it swims head up to the surface, or creeps to it up the bank or along some weed, or pushes through a mass of green algae and, usually tilting the body so as to expose on one side a cleft between head and thorax (for the head has now been somewhat extruded), thrust up the hairy club of the antenna (Plate V, 29, B) and breaks the surface film. It remains in this position for a moment or two and then descends below. When the surface film of water is broken at the aforesaid cleft, a tiny basin or depression is formed there, thus establishing air communication with the underside of the body, the fine hairy covering of which retains a sheet of air. The sides of the prothorax are downbent, the basal part of the abdomen guarded eaves-like by the wing covers, and this structure probably aids in retaining the air that may swell into a bubble. The most anterior of the spiracles (S1) are a large transverse, strongly-fringed pair, situated in the membrane on the underside immediately behind the prothoracic frame. The next spiracles (S2) also large but not hair fringed except very slightly on one side, are secreted on the side of the thorax behind the upper side of a plate known as the katepimeron 2, and sheltered also by the inflexed portion of the wing covers. The third spiracles (S3), hidden under the base of the wing covers, just behind the metanotum but belonging to the abdomen, are large, transverse and well fringed. The several pairs of smaller abdominal spiracles (S4+) following, are on the upper side of

the abdomen and overlayed by the wing covers. They also are in part hair fringed. The large, close-lipped spiracles (S1 and S3), despite their positions, are quite accessible to air that the beetle takes in at the surface of the water; S3 on the back seeming accessible to the air sheet by way of the groove between the uphinging transverse hind coxal plates, and the abdomen. Air is also retained under the wing covers. The large unguarded second pair of spiracles appear difficult of access—as far as inhalation is concerned —and are probably exhalatory in function.

The adult beetle (Plate V, 25) is a mild-mannered creature that appears to be mainly a scavenger and a vegetarian. Dissection of the alimentary tracts of several individuals revealed chiefly a quantity of finely packed, reddish-brown particles that, while probably in part nutritious, certainly suggested the fine deposits or disintegrations on the sides and bottoms of the pools they inhabited. Some fine filamentous algae were also found in the alimentary canal of one or two beetles. In a tiny clear stream on the Island of Maui, some pineapple fruit rinds attracted several of the beetles, and in an aquarium, an individual remained for a day or more feeding at the inner portion of a *Passiflora* fruit. It will also eat of bananas.

The eggs of this beetle are laid in a dirty whitish cocoon (sometimes a little flesh colored) of leathery texture (Plate V, 30) that is elaborated from glands opening at the caudal end of the body). This cocoon, which is about 6-9 millimeters in length—including the strap-like prolongation—is fastened to a water plant, stone or other object, and contains a number of oval-oblong whitish eggs (Plate V, 26) about a millimeter and a half long. Three cocoons contained 13, 14 and 14 eggs respectively. Evidently they are inserted in the cocoon through an opening near the origin of the strap and which is later closed. The period of incubation was not determined but it is longer than that of the *Rhantus* water beetle.[5]

Freshly issued from the egg-cocoon the larva has a dark head and the body quite pale but with a darker shield of good size on the

[5] An egg cocoon formed about November 2 or 3, 1932, and dissected out on November 10, contained 11 eggs near hatching, besides 2 delicate whitish squirming though helpless larvae. The longitudinal pair of tracheae or breathing tubes showed plainly in these larvae and gave forth short air-silvered segmental branches each terminating in a breathing pore or stoma situated at the apex of a finger-like cone that protruded from the side of the body. It appears likely that these newborn larvae and perhaps older ones too, breathe through these lateral stigmatal openings as well as by the terminal breathing cup.

pronotum and a smaller one on the meso- and metanotum, or the upper side of the thorax. It has small antennae, a slightly oblique 5-toothed clypeus, and well-developed mouth-parts (Plate V, 28). The mandibles, similar on each side, have sharp curved extremities and a cluster of three teeth at their middle length, the maxillary palpi are very large and the basal joint armed on the inside with several short stout spines. The body is rather flattish and, in large specimens particularly, with prominent transverse folds or wrinkles. The tail end of the body above, is in part modified into an air cup which connects with the spiracles of the paired longitudinal breathing tubes. This cup which is held to the surface is kept dry and can be partly closed when the insect is submerged, a small bubble then marking its position. Full grown larvae (Plate V, 27), which may be 15 millimeters long, have a dirty brown mossy appearance because of the short hair which covers a large part of the body and helps retain the mud or other fine debris.

The young larva soon raises its head to the surface and drinks in air, plainly visible as bubbles entering the alimentary canal; more grown larvae will also take in air, thus adding to their buoyancy, for if we push a larva under water so that it sinks to the bottom, unless it is able to climb to the surface it will drown. Once at the surface, however, the rather stubby *Limnoxenus* larva with the aid of terminal air-cup into which the longitudinal tracheae

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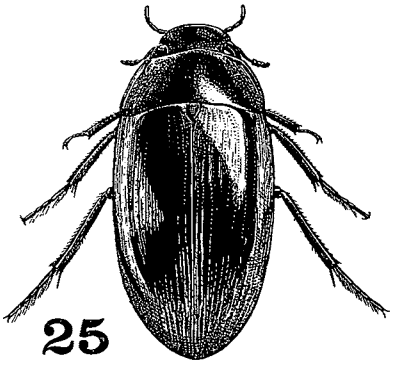
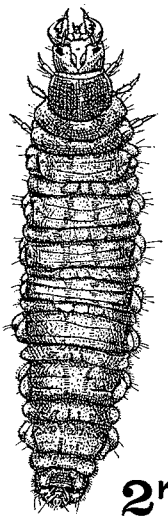
V

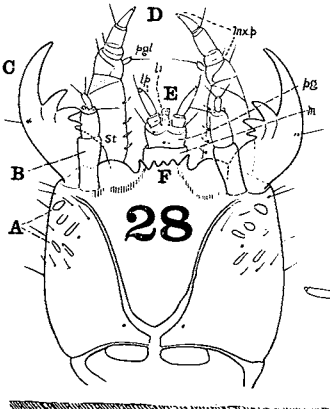
LIMNOXENUS SEMICYLINDRICUS

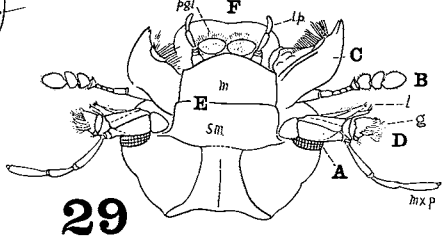
Explanation of Plate

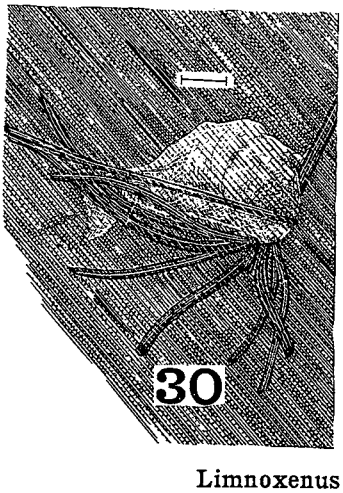
25. Adult beetle. Length 9.5 millimeters.
26. Egg. Length 1.55 mm.
27. Full grown larva. Length about 15 mm.
28. Head of young larva, from above: A, eyes; B. antenna; C, mandible; D, maxilla (st. stipe, pgl. lobe of palpifer, mx.p. maxillary palpus); E. labium (m. mentum, pg. palpiger, li. ligula, lp. labial palpus); F, labro-clypeus.
29. Head of adult beetle, from below: A, compound eye; B, antenna; C, mandible; D, maxilla (l. lacinia, g. galea, mx.p. maxillary palpus); E. labium (sm. submentum, m. mentum, pg.l. paraglossa of ligula, lp. palpus); F, labrum.
30. Egg-cocoons attached to a weed in water. Length 6 mm.
31. Pupa, side view. Length 7 mm.

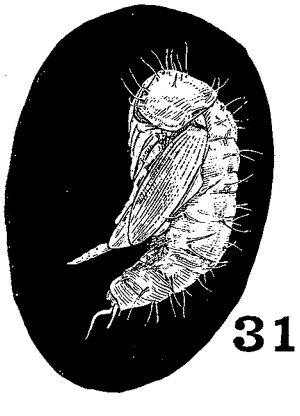












Limnoxenus semicylindricus

lead is able to hang there in a horizontal position. It may even travel upside down at the surface of the water. Locomotion in the water is effected by a violent lashing from side to side of the body so that at the end of each stroke, head and tail seem almost in contact. For all this active movement, however, progress is quite slow. Another means of progression and perhaps the more rapid one is by turning over on the back and swimming at the surface film by regular caterpillar-like undulations of the body. Being so ineffective a swimmer then, this purely carnivorous larva prefers to await its victim than forage for it. If we were to examine the margins of quiet little pools devoid of fish, we might at last encounter there one or more of these soggy-looking larvae, the formidable jaws agape, the tail more or less exposed to air. Or, the quick disturbance of a water weed might dislodge a larva. It is also to be found on dense masses of green algae, at the water line of partly submerged stones, or even in a watery fissure in a rocky bank above water level.[6]

The food of the very young larvae was not noted afield; laboratory examples readily ate small aquatic larvae, as those of mosquitoes. In pools, one specimen was found devouring a smaller one of its own kind, while another was chewing at a psyllid bug that had fallen into the water. But, it would seem that it must sometimes endure considerable fasts. The feeding operations of the *Limnoxenus* larva are interesting even if quite a messy procedure. When it has seized a victim in its strong jaws, it may do nothing more for a while, if the prey be particularly vigorous; at last, however, it backs up, sometimes quite out of water, though itself remaining wet and, holding its prey aloft, commences chewing, passing its prey slowly back and forth across the mouth, the large-spined maxillae alternating with the mandibles in holding the victim against the strongly toothed clypeus, and working it this way and that. In this manner the victim is soon reduced to a crumpled mass that is finally cast away. The head is not invariably elevated however, when feeding.

This insect develops more slowly than the larger water beetle, *Rhantus pacificus,* but like it however, it passes through three larval instars, represented by two moults, with a third moult to trans-

[6] A quite small *Limnoxenus* larva that was progressing along the edge of a pool drew the attention of several large dolichopodid flies (*Dolichopus exsul* Aldrich), which, however, manifested no great desire to tackle this comparatively small larva, though elsewhere this fly avidly seizes the larger bloodworm larva (*Chironomus*).

form into the pupa. No specimens were carried through from egg to adult. The first two larval stages may pass quickly, but active development is withheld in the last larval stage for a period of some weeks, or even months, as far as observations on this species go. A second stage larva secured August 30, 1932, moulted into the third or last larval stage on September 4, entered the ground on about October 30, pupated on about November 9, and issued as an adult on about November 17. On February 8, 1931, an apparently fullgrown larva was found in mud under a stone in the bed of an intermittent stream at an elevation of about 2,000 feet in the Koolau Mountains, Oahu. It was kept in a small vessel with mud and water and was occasionally offered food, which, however, it accepted but infrequently. It died towards the end of June, or after a captivity of over 4 months.

This "wintering" as a large larva, has been observed in a related beetle (See Richmond, E. A., 1920).

At the end of October one of my *Limnoxenus* larvae crawled up the muddy bank of its small prison and dug a cell under a stone, and plugged up the entrance to this cell. It worked at the cell for a day or two, then cast its skin to turn into a delicate yellowish white pupa (Plate V, 31) that was provided, especially on the thoracic plate and sides and back of the abdomen with large hairs that were rather stout for their basal portion. The pupa rests upon its back, the hairs keeping its body well up from the damp floor of the pupal chamber. In about 10 days the adult beetles issued.

The beetle of course flies well.

According to Coleopterorum Catalogus, W. Junk: Pars 79, Hydrophilidae, by A. Knisch, 1924, the genus *Limnoxenus* Motschulsky, is composed of 3 species (with 3 others regarded as doubtfully valid). Of these *L. niger* Zsch. is mid-European, *M. zeylandicus* Broun, is Australasian, as are two of the species considered doubtfully valid. Our Hawaiian species then, two in number, if we consider *L. nesiticus* Sharp and which in the Catalogus is regarded as doubtfully valid,[7] are the farthest outposts in the Pacific. These two were until rather lately, placed in the genus *Hydrobius,* with its 8 or more species. In *Hydrobius* belongs the

[7] *L. nesiticus* is readily distinguished from the common *L. semicylindricus.* Dr. Perkins collected three examples of this species far up Kawailoa Gulch, Oahu, April 1893. It has a wider head, a more slight development of the mesosternal keel and deeper and coarser sculpture than *semicylindricus.*

widely distributed *H. fuscipes* (L.), the biology of which has been written by L. C. Miall in his Natural History of Aquatic Insects, 1895, and F. Balfour-Browne, in the Transactions of the Royal Society of Edinburgh, XLVII, pp. 317-340, pl. III, 1910. For an interesting work on the life-history of *H. globosus* (Say) and other hydrophilid beetles, see Richmond, E. A.; Studies on the Biology of Aquatic Hydrophilidae, Bull. Amer. Mus. Nat. Hist. XLII, Art. I, pp. 1-94, 1920. The biology of our *Limnoxenus semicylindricus* corresponds closely to that of *H. globosus,* its rather near relative.

Enochrus nebulosus (Say).[8]

Hydrophilus nebulosus Say, Exp. Long. II, p. 277, 1824.
Enochrus (Lumetus) nebulosus, Knisch, Coleopterorum Catologus (W. Junk), Pars 79, pp. 210-211, 1924.

The haunts of *Enochrus nebulosus,* the little brown hydrophilid beetle (Fig. 32), may not be attractive. We must seek it in shallow, often somewhat saline waters that are frequently choked with the succulent scrophulariaceous plant, *Herpestis monniera* H. B. K., that harbor green algae and other submerged plants and to one side perhaps, with an invading forest of rushes (*Scirpus lacustris* L.), in or near abandoned rice fields, and swamps of sweeter water where various grasses, *Scirpus,* areas of Parrot's feather (*Myriophyllum proserpinacoides* Haloragaeae), the little floating duck-

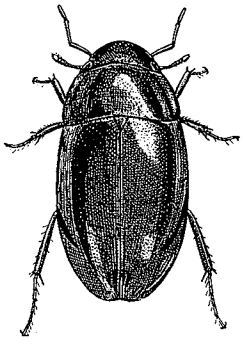
[8] Identified by Dr. E. C. Van Dyke.

VI

ENOCHRUS NEBULOSUS

Explanation of Plate

32. Adult beetle. Length 3.5 millimeters.
33. Pupa, from beneath.
34. Young larva showing air bubbles it has swallowed.
35. Full grown larva. Length about 7 mm.
36. *Lemna* plant with the egg-sac of the beetle fastened to its roots. Egg-sac without strap portion is 2.10 mm. long.
37. Eggs, well incubated. Length 0.7 mm.
38. Head of young larva, from the side, to show how the maxillae, MX, are developed to assist the mandibles, M, in mouthing food. A, antenna; L, labium.



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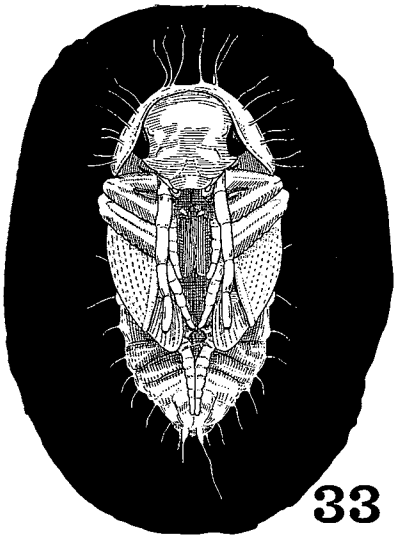

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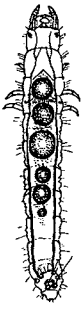

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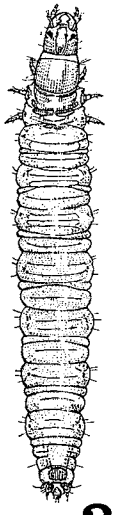

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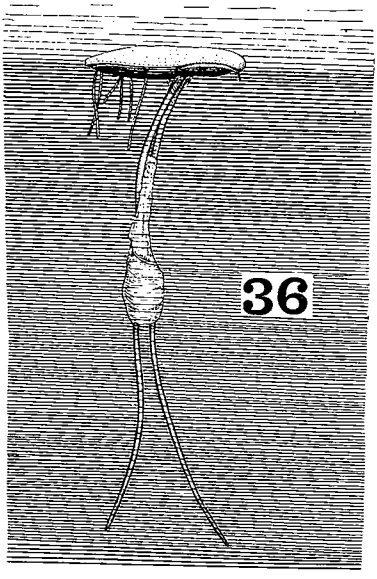

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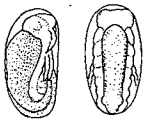

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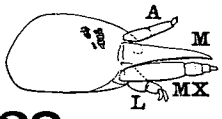

38

Enochrus nebulosus

weed (*Lemna*), etc., combine in a dense growth, and finally, in the floating mats of filamentous green algae that often cover portions of our plantation reservoirs. Thus, it frequently shares its habitat with the tiny *Hydrovatus confertus* (Dytiscidae) beetle and with the very convex shining black hydrophilid beetle, *Coelostoma fabricii* (Montr.), a semiaquatic species that is an even poorer swimmer than *Enochrus*.

The *Enochrus* beetle (Plate VI, 32) is about 3.5 millimeters long, somewhat elliptical in form, not very closely knit, with short clubbed antennae, long maxillary palpi, and legs that are hardly fitted for swimming. It is, however, well suited to its environment, creeping among the plant growth and pulling itself underwater, since it is too buoyant and too feeble a swimmer to descend otherwise. Under water *Enochrus* can run nimbly along stems, etc., and it will run up to the surface, take in air at its head end and then retreat below. Frequently however, it gains the surface by simply loosing its hold, when it floats up very rapidly. Back upwards, it swims in rather a wobbly manner or, turning over so as to expose its flat air-silvered underside it runs more effectively just beneath the surface film of water. The beetle is commonly observed along the margin of shallow water. Captive specimens will crawl up the glass sides of their prison at night and take wing. In confinement they will also form and fill their dirty whitish egg-sacs, attaching them to dead leaves, the stems of plants, debris, etc. The egg-sac illustrated in Plate VI, 36, is fastened with the strap, or "mast" end up, to the roots of duckweed (*Lemna*). Altogether, it is about 5 mm. long and contains 12 eggs. Two well-incubated eggs are shown in figure 37. They measure 0.7 mm. long.

The duration of the egg stage was not ascertained for Hawaii. In New York, E. A. Richmond (1920) found that eggs of this species laid in spring hatched in 9 days. The larvae do not immediately leave the egg-sac. A freshly issued larva is a little over 2 mm. in length (Plate VI, 34). Like the rather more stoutly formed young of *Limnoxenus,* its larger Hawaiian cousin, it gulps down air that passes as silvery bubbles into the alimentary canal and thereby renders this poorly-swimming creature quite buoyant. In a partly-grown *Enochrus* larva this air gave the crop a silver lining. The insect always strives to keep its respiratory cup to the

surface; this apparatus, situated at the posterior extremity, connects with the longitudinal breathing tubes or tracheae.

Little attention was paid to the feeding habits, moulting, etc. The larva is carnivorous and must find ample food in the small organisms, Crustacea, tiny worms, fly larvae, etc., that often swarm in its environment. The *Enochrus* larva is quite active, creeping about caterpillar-like along the muddy margin of the shallows and among weeds in the water. It is probable that it seldom ventures in open water for, not being thoroughly aquatic it is a poor swimmer. It can, however, make a little progress in the water by lashing the body from side to side, or, to better advantage, though still quite slowly, by turning on its back and undulating along. When thus venter up, one notes the six pairs of low prolegs, or false feet, on the abdomen.

The *Enochrus* larva most probably has two moults, and a third moult to disclose the pupal stage. A full grown larva (Plate VI, 35) is about 7 mm. long, with a pale brown head, a good prothoracic shield, a smaller mesothoracic, and a fragmentary metathoracic one. The body is paler than the head, and divided by many transverse folds or wrinkles. It much resembles a small *Limnoxenus* larva, but is more slender and cleaner looking. The longitudinal air tubes are clearly visible from head to tail and a tracheal branch on either side goes to the spiracle at the side of the mesothorax. It assumes much the same posture as *Limnoxenus,* the head being inclined up a little while the tail end reaches up for air. Its maxillae are well developed and are employed in conjunction with the mandibles (Plate VI, 38) in manipulating its prey. The pupa (Plate VI, 33) is glassy creamy white with the eyes dark. It is stout and arched and furnished with long hairs from thickened bases and they serve to keep the pupa clear of the moist cell bottom. Larvae reared in captivity pupated in the inner concave, much decayed surface of a portion of *kukui* (*Aleurites*) nut rind that with mud and other debris formed an island afloat in a large jar of water. The pupal stage is very brief.

Enochrus nebulosus has been collected thus far only from the Island of Oahu of the Hawaiian group, and where it was first collected in 1914 by O. H. Swezey. It is a widely distributed species and belongs to a huge genus.

The subfamily Sphaeridinae of the family Hydrophilidae is represented here by several widely distributed species. They are small jet black insects of very convex form that for the most part live among manure, vegetable refuse, or in very stagnant weedy waters. Their thickish larvae are predacious, feeding largely upon the young of insects they are able to overcome. Several species were introduced here from the Orient to combat the sugar cane weevil borer but did not become established. Of the genus *Dactylosternum* we have *D. abdominale* (Fab.) and *D. subquadratum* (Fairm.). The first of these is nearly cosmopolitan while *D. subquadratum* described from Tahiti is fairly common in Hawaii and is recorded also from Samoa, Fiji, Buru, Borneo and the Philippines. Both of these beetles have the wing cases finely marked with nearly parallel dotted lines or elytral striae. *D. subquadratum* usually inhabits refuse, has been taken rarely under wet pebbles by water or at the edge of a tiny pool in the hills behind Honolulu.

Coelostoma fabricii (Montr.) (Ann. Soc. Ent. France (3) VIII, 1860, pp. 245-246) described from New Caledonia and of which *C. extrancum* Sharp of Oahu, Hawaiian Islands, is regarded as a synonym, occurs also in Australia. It is shining black, about 6.5 mm. long and its whole upper surface is dotted with tiny close-set punctures (Plate IV, 24). It is common in the lowlands of Oahu and occurs also on Molokai and probably elsewhere in the Archipelago. It is often found in company with the smaller, relatively more elongate brown *Enochrus nebulosus* and is quite at home in muddy shallows and in foul brackish water choked with vegetable growth and odorous of sulphur. Although a poor swimmer indeed, it can turn very deftly on its back and run along thus with its air-silvered underside just below the surface film of water. It often descends under water by creeping down some partly submerged plant or other object. The adult beetle is probably chiefly a feeder in vegetable matter and several individuals that I placed with a piece of papaya soon penetrated this soft fruit and could be seen moving their jaws within it. The leaves of Asiatic pennywort (*Hydrocotyle asiatica* Linn.) were also eaten by *Coelostoma* beetles. Captive specimens formed lens-shaped egg cases with a wide thin margin and somewhat suggesting the egg case of a spider. They were dirty whitish, rather tough, about 4.75 mm. in

the diameter of the double convex portion and were fastened flat to a bit of floating wood. One case was opened and found to contain 11 eggs arranged in 3 tiers enclosed in a rather fine fibrous sheathing material. The young larvae are of stout form and, as in *Limnoxenus* and *Enochrus,* imbibe air.

The dentition is alike or with quite minute variation in both mandibles.

PART II. ORDER ODONATA (DRAGONFLIES AND DAMSELFLIES)

Professor C. H. Kennedy (The Origin of the Hawaiian Odonata Fauna and its Evolution within the Islands, Proc. of IV Intern. Congress of Entomology, Ithaca, Aug. 1928, 1929, on pp. 978-979) writes as follows: "The Odonata fauna consists of about forty forms in thirty distinct species, the other ten being geographical races. Five species are Anisoptera. The remainder are a closely interrelated group of Zygoptera, all belonging to the supergenus *Megalagrion,* named so for the very large size of some of the species. This genus is so closely related to the oriental genus *Pseudagrion* that the more generalized species of *Megalagrion* could be placed in *Pseudagrion* without hesitation, if found in the Orient."

The Anisoptera or dragonflies are characterized as adults in having a relatively stout body, with wings held horizontally when at rest, the hind wings being broader at the base than the forewings, and the young variously known as nymphs, naiads or larvae, in having the "gills" within the stout spine-tipped abdomen, and in the squirt method of swimming. The Zygoptera or damselflies are of more slender form with the fore and hind wings of practically the same shape and size and usually held together or slightly apart over the back when at rest, and with the nymphs with three more or less flattened gill plates at the end of the abdomen, and swimming by a wriggling or sculling motion.

Two of the dragonflies and all of the damselflies are found nowhere else in the world, and thus the Hawaiian Odonata fauna is 90% endemic.

SUBORDER ANISOPTERA (DRAGONFLIES)

FAMILY **AESCHNIDAE**

Anax strenuus Hagen.

Anax strenuus Hagen, Verh. Ges. Wien, 1867, p, 34 (♀); Blackburn, Ann. Nat. Hist., (5) XIV, 1884, p. 413 (♂).

It is only here and there among our native insects that we find really large species. The giant Hawaiian dragonfly, *Anax strenuus* (Plate VII, 39) is one such. Not only is it the largest dragonfly in the Territory, but it surpasses in expanse of wing, if not in bulk as well, *Anax walsinghami* McLachlan, the largest dragonfly in North America.[9] The wing expanse of *strenuus* is usually at least 5 inches (127 millimeters); those measuring 132 millimeters are common, while the largest specimen that has yet come to my notice is in the Bishop Museum, Honolulu, and spans 143 millimeters. A specimen reared by the author measures 142 mm., or 5⅝ inches. A pair of these giants hovering close at hand tandemwise over the water appears hugely out of proportion with the rest of the insect population. As these insects rather leisurely pass beyond us along some little mountain stream, the male can be readily distinguished from the female by the conspicuous blue area just behind his thorax. And when one pauses nearby in its exploratory flight we see the immense eyes alive with light, the spiny legs folded against the breast, and hear the gentle rustling of rapidly moving wings. Sometimes one may be seen dipping its abdomen in the water, or more rarely perhaps, dashing itself again and again flat upon its surface, fluttering there a moment, and then easily arising from it. When hovering low over a pool, the water beneath it trembles from the draft caused by its fanning wings. Capable of great speed it will dart up or down some watered canyon or

[9] Needham and Heywood, 1929, p. 130. Expands 122 mm. Seeman, Theresa M., 1927, p. 24: "Expanse of wing 114 to 126 millimeters". "The largest species, the most gigantesque of recent Odonata, is *T.* (*Tetracanthagyna*) *plagiata* Waterhouse, recorded from Borneo, Sumatra and the Malay Peninsula. The female may have a span of over 170 mm." [up to about 7 inches]. Laidlaw, F. F., The Dragonflies (Odonata) of Burma and lower Siam—III, Subfamily Aeschninae, Proc. U. S. Nat. Mus., 62, Art. 21, 1923, on page 18. This expanse of wing however, may be exceeded by the very slender damselfly (Zygoptera) *Megaloprepus coerulatus* Drury, from Central America and the females of which sometimes measure 190 mm. across expanded wings.

course high in air about a mountain top.[10] It is a familiar insect of the upland roads of many sugar cane plantations, but may also be found in certain localities at sea level. Quick to perceive its prey, the larger damselflies are among the victims of its rapacity.

While the two species of Anax (*A. strenuus* and *A. junius*) may be distinguished by structural characters (Plate VII, 40 and 41), tandems consisting of the male of one attached to the female of the other have been observed by Perkins (Fauna Hawaiiensis, Introduction). Apart also from the difference in size and structure, the costal or front margin or vein of the forewings of *strenuus* is mainly quite dark, whereas it is pale in *junius*.

During late November, 1933, while studying aquatic insects in the mountains of East Molokai, a few notes were made on the egg-laying of this dragonfly. The locality was at an elevation of about 2,100 ft., where the clear Moaula stream, wedged in a canyon luxuriant with vegetation, flows seawards, quickening its pace to lower levels by a succession of waterfalls that culminate in the lofty Halawa Falls nearly two miles away. The fauna of at least the upper portion of this stream appears rather scant. The curious Hawaiian goby or *oopu*, so abundant at lower levels seems uncommon at 2,100 ft. The fresh water shrimp (*Atya*) on the other hand, is numerous here. Both fish and shrimp, then, are able to surmount large waterfalls.[11] There are some aquatic snails, several species of damselflies, as well as certain chironomid flies (*Tanytarsus* and *Telmatogeton*) found also in these upper waters. Noteworthy though rather solitary in habit is the fine, almost ma-

[10] Although dragonflies number among the swiftest of flying insects, their powers of flight are due to the superbly balanced proportions of wings and body rather than to any great muscular power, which indeed is considerably exceeded by many insects. Hold for example, a thick-bodied moth, butterfly or a skipper butterfly by the wings brought together over the back and compare their muscular exertions with that of a large dragonfly held in a similar manner.

[11] The ventral fins of the goby are united into a sucker-like disc by the aid of which it is evidently able to climb up very steep places. A note on the climbing ability of the shrimp is as follows:

In July 1932, while in the upper sugar cane lands of Onomea Sugar Company on windward Hawaii, the writer observed young *Atya bisulcata* shrimps between a half inch and one inch in length, travelling up a V-shaped wooden flume 1/3 full of water estimated to be running at about 15 miles per hour. By means of a loose plug or dam of weeds the flow of flume water had been diverted over the side whence it made its rapid way, almost as a cataract, to a natural stream in a canyon several hundreds of feet below. This was the source of the shrimps that somehow climbed up, and then through the weeds and debris at the overflow of the flume, somewhat raised from the ground; they conquered the overlapping boards in the flume section and made their way presumably, to headwaters. I saw 20 or more of these crustaceans working their way up against the flume current. They were in the edges of the flow; just completely under water or awash so as to form a ridge there. One could see their antennae. In progressing, they walked from one to several inches and then paused. They could see well enough and leaped full in the water when I attempted to capture them.

jestic, brilliant green *Liancalus metallicus* Grim, that giant among Hawaiian dolichopodid flies. Perched warily head upwards upon a moist boulder, often in midstream, at the plunge of, or alongside a cataract, this big fellow demands cautious stalking and a swift and accurate swing of the net for its capture.

At this 2,100 ft. level then, about a small area of quieter water in the Moaula stream, I chanced upon two tandems of *Anax strenuus* searching for a place to oviposit. The males of one or both of these tandems were rather quarrelsome, for, encumbered though they were with mates, one would attempt to drive away the other. Soon getting down to business however, the tandems again flew about rather slowly, searching the rocks and debris in the water, and one pair choosing an old, water-soaked piece of *ieie* vine (*Freycinetia*) stem, alighted on it. Now the rear insect or female of the tandem, inserted her abdomen part way under water along the stem and drawing back the stout curved ovipositor situated near the extremity of the abdomen and that when not in use fits into it much like the blade in a clasp-knife, she forced it into this stem and with a saw-like motion cut a slit. This operation was repeated again and again, the thorn-like ovipositor securing a new purchase after every slit. The actual insertion of the eggs was not observed, but an examination of this *ieie* stem revealed a number of *Anax* eggs each in a slit cut at a slight angle from the surface. Some of these eggs were so shallowly imbedded as to be exposed

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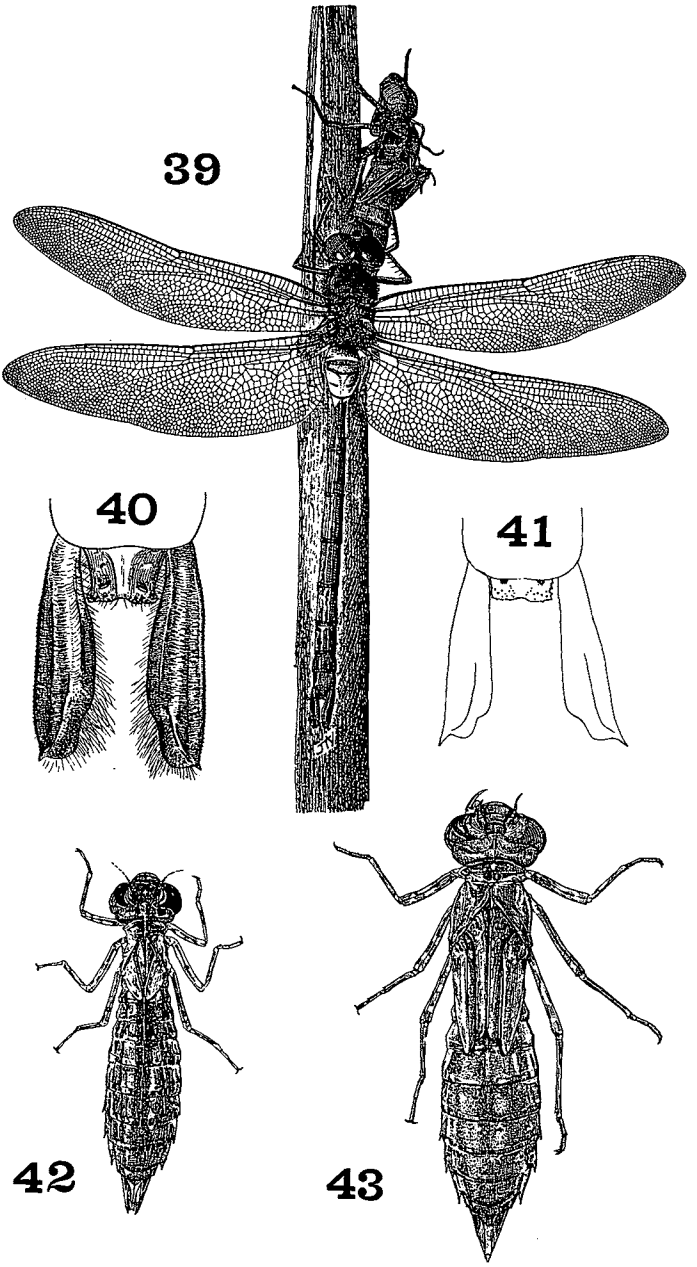
VII

Explanation of Plate

39. *Anax strenuus,* the giant Hawaiian dragonfly a few hours after emergence from the nymph, to the empty skin of which it partly clings. This is a male that has a wing expanse of 137 millimeters, or 5 3/8 inches. From a photograph by W. Twigg-Smith.
40. *Anax strenuus,* male, showing superior (paired) and inferior anal appendages. From above.
41. *Anax junius,* male showing (in outline) the superior and anal appendages. From above.
42. *Anax junius,* nymph about three-quarters grown. Length 35 mm. From a photograph by W. Twigg-Smith.
43. *Anax strenuus,* nymph, a day and a half before producing the adult. Note that the wing pads and the thorax are swollen and the antennae and mouth parts are no longer functional. Length 54 mm. Waianae Mts., Oahu. From a photograph by W. Twigg-Smith.



Anax strenuus and **junius**

at the surface for a good part of their length; in any case, the end that bore the horny cap was more or less exposed or even protruding. Eggs of *Anax strenuus* are commonly inserted in submerged portions of the often semi-aquatic *honohono* (*Commelina nudiflora*) and no doubt at times are intermingled with those of *Anax junius,* its lesser relative of generally lower levels, the range of these two insects overlapping however. Likewise, a *Commelina* stem may in addition to the eggs of *Anax* bear many eggs of damselflies (*Megalagrion*).

The eggs of *A. strenuus* (Plate VIII, 44-47) are perhaps more usually arranged in a double row that may be slightly oblique to the length of the plant stem into which they are inserted. They lie head outwards and upwards and may be from a little less, to a little more than 2 mm. long, or as much as 2.25 including the somewhat darker cap at the head end. The egg of *A. junius* is somewhat smaller. The incubation period was not positively determined; but on the mainland of the United States it has been found to be about three weeks for *A. junius.* The insect issues from the egg as the "pronymph" or first larval stage. It then resembles somewhat a tiny pupa enveloped as it is in a tight chitinous membrane and with the legs glued to the body. This stage is of exceedingly brief duration (3 to 20 seconds in *Anax,* according to Tillyard, 1917),

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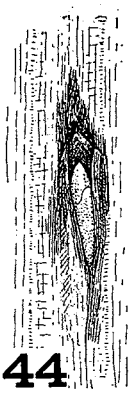
VIII

Explanation of Plate

44. *Anax strenuus,* egg imbedded in stem of *Commelina nudiflora.* Enlarged.
45. *Anax strenuus,* egg from side; cap at upper end. Length about 2 mm.
46. *Anax strenuus,* pronymphal skin extruded from shell.
47. *Anax strenuus,* egg shell with emergence slit.
48. *Anax strenuus,* nymphal stage immediately following pronymph. Length about 2.6 mm.
49. *Anax strenuus,* nymphal stage following figure 48; showing respiratory system, the branchial basket lying chiefly in the yellow abdominal band. Within the dark abdominal band and just behind the pale thorax, and commencing between the converging air tubes or tracheae are the oval-shaped remains of the yolk in the midgut. Length about 3 mm.
50. *Anax junius,* egg well incubated.
51. *Anax junius,* young nymph, showing incipient wing buds between base of posterior legs. Length 12 mm.
52. *Anax strenuus,* egg, parasitized by an *Anagrus* wasp, at W.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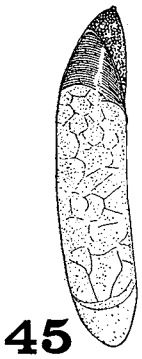
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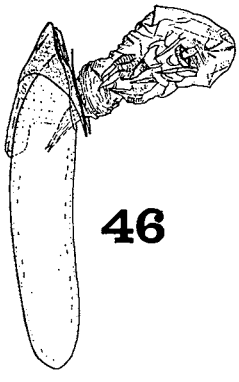
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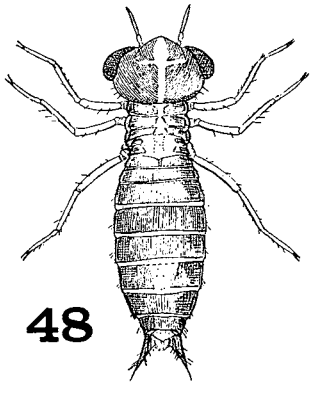
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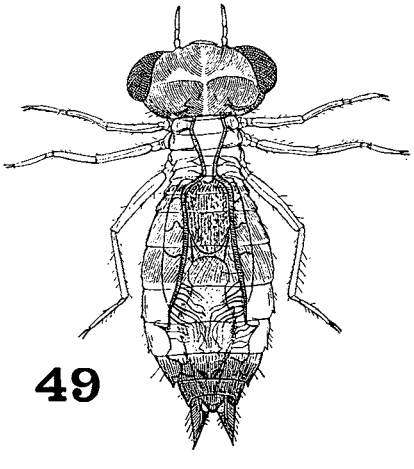
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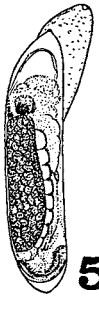
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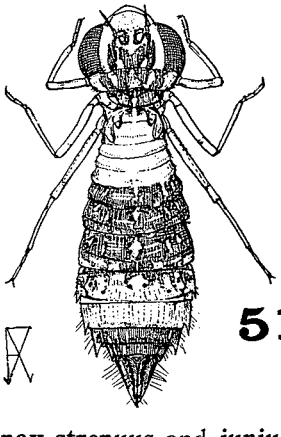
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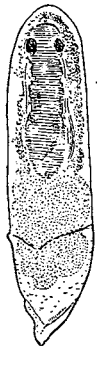

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Anax strenuus and **junius**

and during these few seconds it moves very little, since it may not entirely free iself from the egg slit (Plate VIII, 46). When the first moult, producing the second stage larva or nymph occurs we have a diminutive though active insect, the dark brown shade of which is varied chiefly by a pale canary yellow cross on top of the head; this yellow is continued along the dorsum of the thorax, beyond which it finally diffuses a good deal and further along the abdomen is represented by rather obscure pale bands (Plate VIII, 48). When we see one of these tiny larvae swimming rather tediously in open water—wriggling the body, moving the legs, and expelling water from its tail end—we realize that it has reached a stage in its existence that is fraught with peril. The little pool in which these midgets were observed navigating contained also voracious *Rhantus* larvae and probably the adult beetles as well. But locomotion in the young *Anax* nymph soon improves and it becomes more addicted to clinging quietly to some submerged stone, root or twig, and to darting out at some small moving organism, or perhaps stalking it with no little skill. With more growth it is able to swim in a swift darting manner by vigorously expelling water from the hind end of the alimentary canal wherein the respiratory organs are situated. Pale yellowish markings persist with some changes through several moults, disappearing however, well before the larva is half grown, when it is mainly brownish or slightly dark olive greenish, variegated somewhat by paler and darker markings. The legs are pale banded. The *Anax* larva sheds its skin a number of times, soon acquiring little wing pads that increase in size with each moult, the compound eyes also growing larger and nearer together. Directly after each moult it is very pallid and greenish except for the dark eyes, and tips of the mandibles and maxillae. It is then comparatively helpless and so rests quietly until the integument darkens, becomes tough and the insect is again strong and active. Finally, it reaches a length of two inches or more. The large dragonfly larva is a dark and sinister inhabitant of the deeper pools of mountain streams, and is not immediately to be discerned as it rests in immovable expectancy, one might say, of a meal, among the somber boulders, submerged twigs, or on the bottom itself. Sometimes this keen-sighted insect ventures towards the shore, and my approach to a pool would occasionally be a signal for both tadpole and *Anax* to scoot to shel-

ter. By reason of the reflection upon the pool, its ledge-like banks and the large boulders that help shape it, the wary larva is often difficult to capture; an appeal to its appetite, however, in the form of an earthworm dangling from a string into the depth, will sometimes lure it within reach of a cautiously wielded net. It feeds upon damselfly larvae, smaller examples of its own kind, larvae of chironomid flies, occasionally the larvae of the *Hydrobius* water-beetle, drowning earwigs and undoubtedly upon many other insects that fall into the water. Unidentified remains of a small crustacean have been found in its alimentary canal, as well as the long-conical shells of the common aquatic snail *Melania,* and those of the stouter and smaller ones (*Physa* or *Lymnaea*). The smaller shells may be swallowed entirely but larger ones are broken up in its jaws with quite an audible gritty crunch. Aquatic mites (acari) fall a prey to the smaller larvae. And no doubt, the tadpole of *Rana rugosa* Schlegel, the little Japanese frog so abundant in some of our streams, is on the bill of fare of *Anax*. Large dragonfly larvae are well known as enemies of small fish but in turn serve as food for larger ones. Upon spying a prospective victim this big dragonfly becomes the picture of stealth, and so very gradually at last, may it approach the object of its desire that it usually succeeds in capturing it by means of the hinged mandibulate labium or lower lip, which is shot out with great rapidity.[12] Frequenting the same pools as *Anax strenuus* is the little native shrimp (*Atya bisulcata* [Randall]) of our mountain streams. This vigorous and hard-shelled crustacean is often very numerous but I do not think that at least in its later stages, it suffers much from the attacks of this dragonfly nymph. In close quarters however, where attempt after attempt can be made, *Anax* may be finally successful. Dr. Edmondson in his paper on Hawaiian Atyidae (Bernice P. Bishop Museum, Bulletin 66, 1929) on page 31, writes: "Dragonfly nymphs are common inhabitants of mountain streams. A very large one attacked and almost instantly killed an adult shrimp when the two were released in a small container". Two large *Anax strenuus* nymphs that I confined with *Atya* shrimps, did, after a num-

[12] Here, however, we must often except the common top minnow *Gambusia affinis* (Baird and Girard), a very alert and active little fish. When a number of *Gambusia* were placed in aquaria each containing a large nymph of *Anax strenuus*, one or two of the fish—perhaps dazed or injured—were very soon captured and devoured. But as soon as the other fish got their bearings, they anticipated, as it were, the moves of their stealthy foe and usually evaded capture.

ber of unsuccessful attempts, succeed each in grasping a crustacean by the tail and despite vigorous struggles, consumed them.

While *Anax strenuus* seems to favor clear stream waters, it may be successfully reared in an ordinary well aerated aquarium of moderate or even small dimensions. Though naturally a wary creature, it will learn to seize living food offered it with a pair of forceps. Thus I have fed one with medium large cockroaches and grasshoppers, and also flies skewered on the end of a piece of broom wisp. If the prey be large and vigorous it is held off a little in the extensile labium (Plate IX, 57), somewhat as one would a sandwich, to be leisurely bitten into. It is very particular, however, that the struggling prey does not lay strong hold of its own body. A long-horned grasshopper, *Conocephalus saltator* (Sauss.), a capable insect with its jaws, was once incorrectly seized, with the result that it firmly grasped its would-be captor by the fore part and evidently gave it a good bite; the *Anax* larva immediately resorting to its usual mode of defense, writhed and, bending forward the abdomen, dislodged the orthopter by a jab or twist of its spiny tail, and then dashed off. For a while at least, thereafter it was more cautious about seizing its prey. An *Anax* larva devouring a soft slippery tadpole is not a particularly pleasing sight. The

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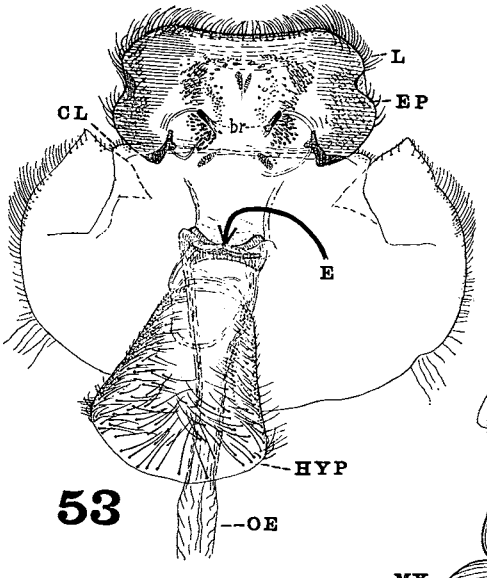
IX

ANAX STRENUUS

Explanation of Plate

53. Adult. Lower front portion of head, to show labrum or upper lip L (underside); EP, epipharynx, with its hair brushes (taste organs ?) br; CL, lower corner of clypeus; HPY, hypopharynx—a sort of tongue—bent back (down) to show at point of curved arrow E, the entrance to the throat or oesophagus OE. Inside view.
54. Adult. Maxilla: C, cardo; ST, stipe; P, palpus; IL, inner lobe; a, a, a, movable teeth.
55. Adult. Right mandible. MM, muscles.
56. Adult. Labium; SM, submentum; M, mentum; sq, squama; ml, median lobe; ll, lateral lobe; mh, movable hook; eh, end hook.
57. Full grown larva. Head from beneath, with "mask" or labium unfolded back and the right maxilla removed; L, labrum; EP, epipharynx; MD, mandible; MX, maxilla; HYP, hypopharynx; E, eye; SM, submentum; M, mentum; ml, median lobe; ll, lateral lobe; mh, movable hook; eh, end hook; t, tendons.



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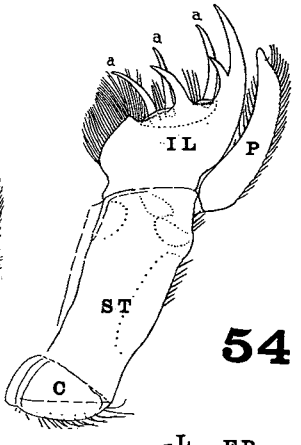

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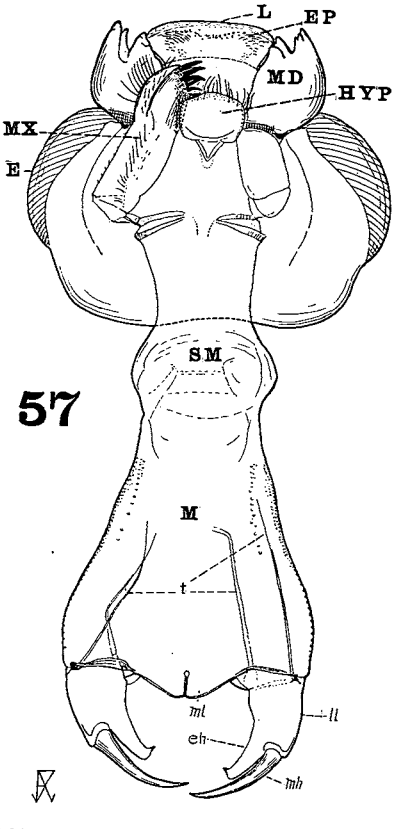

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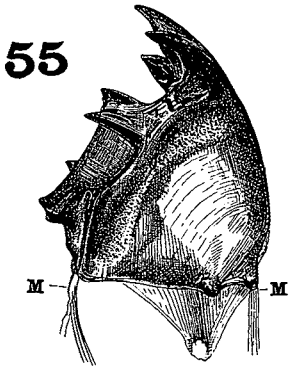

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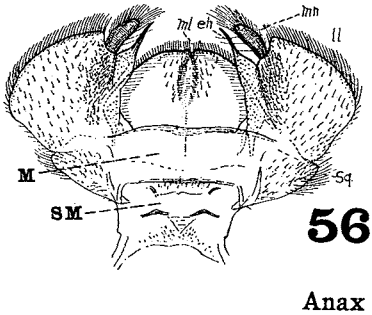

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Anax strenuus

larva holds its hard-breathing victim in a bulldog grip against its sudden and violent struggles and very deliberately consumes the unfortunate creature. A small geckonid lizard offered to a large *Anax* larva was quickly seized, but the integument of the reptile proved too tough and so, after some chewing, was abandoned.

From a few eggs found imbedded in *honohono* (*Commelina*) stems growing partly in the little Kukuiala stream, Waianae Mts., Oahu, on September 16, 1933, several *Anax strenuus* larvae had hatched by the end of that month. These were kept together in a good-sized aquarium having sand on the bottom, some stones, a few lengths of *Commelina* stems and a mass of filamentous green algae at one side. The larvae of the *Tanytarsus* midge, damselfly larvae and other insects furnished food for these *Anax,* which however commenced preying on one another so that soon very few were left, and at last but one remained. This one, usually well supplied with food increased rapidly in size and finally attaining a length of 54 millimeters produced an adult dragonfly during the dark of the morning of February 10, 1934. Thus, for the full development from the laying of the egg to the hatching of the adult *Anax* about 5 months were required. This is a brief period of development when compared with that of *Anax junius* on the mainland where a real winter retards growth so that nearly a year elapses before the insect has passed through all its stages.

At 5:20 p.m. of January 5, the *Anax strenuus* larva above referred to moulted into its last larval stage. It measured 46 millimeters in length prior to this moult, when it was clinging subvertically head upwards to a stone. Through the integument of the dorsum of the thorax a white spot representing part of old tracheal or breathing tube lining became apparent. It is about this region that the integument splits right down the middle, separating also at the back of the head and along the inner margin of each eye. A pale green swelling now bursts through the thoracic fissure while anteriorly, a large new head, also greenish save for the dark eyes and tip of mandibles and maxillae, is emerging from the cracked head shell. Meanwhile, the "mask" or jointed labium with which prey is captured, extends backwards towards the breast. As the new-skinned larva, its head bent somewhat breastwards, almost imperceptibly works itself out of the dark integument, by expanding and contracting the abdomen it seems, the appendages are suc-

cessively freed—the wing pads, the mask, and then the legs—these are all immobile and extended backwards. The abdomen gradually slips from its old casing until only its apical fourth or so remains within. The mask at first slowly, and then rather quickly, folds up loosely under head and breast and finally, the legs, which have moved very little, now reach forth, grasp the old shell, or exuviae, and quickly pull the abdomen entirely free. Up to this point some 12 minutes have elapsed. The soft larva now is almost entirely pale green, giving it a rather unsubstantial and almost ghostly appearance. Some brownish is visible in the abdomen. Forty-five minutes after the commencement of the moult the color of the larva is apparently unchanged, but at 8:10 p. m. it has darkened and some brownish markings are evident on the back and sides. The color, a sort of olive green, becomes darker and darker. I fed it again. By January 14 it has grown considerably, measuring 54 millimeters in length and is of a dark olive green color with some dull brown. It becomes browner and browner, that color being quite evident on the wing cases and a broad dorsal thoracic area. By January 21, the thorax appears to be somewhat swollen. More and more does the thorax swell and the wing covers, now pale brown, have also thickened (Plate VII, 43). Later on, it takes no food,[13] becomes rather inactive and, finally abandoning the rapid squirt method of progress, turns head up and breathes air at the surface by one or both of the large thoracic spiracles (mesostigmata). In the darkness of the early morning of February 10, it climbs up a stick, and well out of water, moults for the last time to transform into a fine large aerial dragonfly. Upon liberating a newly matured though vigorous *Anax* it ascends steadily into the air to a great height.

A second *Anax strenuus* reared from one of a number of eggs found imbedded in the leaf-sheath stem of a stray taro plant (*Colocasia antiquorum* Scott, var.) in a mountain stream on June 16, 1935, shows development and moults as per following table:

[13] When in this state *Anax* nymphs will reside peaceably together in a small receptacle, where otherwise one would soon devour another. The writer kept together for over a week a nymph of *Anax strenuus* and of *A. junius* that in their sluggish swollen state shared the same emergence stick. The larva of the *A. strenuus* took no food for at least 10 days prior to hatching into an adult. This semiquiescent state might well be likened to the pupal period of insects with complete metamorphosis, since in both cases the tissues are being altered into those of the adult insect.

Instars:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Days duration:	a few seconds?	?	5½	7-8	5-6	4	6-7	6-7	14	5	8	21	22	37-38	38-39
Number of antennal joints:		3	4	4	4	4	5	5	5&6	7	7	7	7	7	7
Number of tarsal joints:		1	2	2	2	2	2	3	3	3	3	3	3	3	3
Wings:					Rudiments		increasing in size								
Length in mm.:		2.6					increasing in size								53

The egg hatched about June 18 or 19. The pronymphal or first instar lasts probably less than a minute. Disproportionate duration of some of the instars is probably due to a varying food supply. The last several instars are naturally quite long. In its ultimate or 15th instar this nymph's final meal was on the morning of December 7. At that time it was still a good swimmer, but the wing pads were beginning to swell and stand apart. The adult dragonfly, a male, hatched on December 21 or 22 and measured 133 mm. or 5¼ inches across outspread wings.

Several of these insects were noted at various steps in adult development. The larvae or nymphs always left the water under cover of darkness, climbing up some convenient object; in captivity a twig or leaf, in nature usually the underhanging side of a large boulder by, or in the stream. A light seemed to disturb them. Hanging securely from its perch, the larva undergoes some slight movements which assist no doubt in future development; in due time the integument of the swollen thorax bursts above, the integument of the head likewise, and the thorax and head of the adult insect appear through these breaks. When it has issued from the larval shell as far as the basal part of the abdomen, the developing adult is hanging curved back and head-downwards. It remains in this position for a time immovable or almost so, except for an occasional twitch. Finally, as if suddenly coming out of a trance, it bends up and forward and with now extended legs grasps the portion of the larval shell before it, and pulls itself entirely out of it and hangs freely head up. Now puffy, huge-eyed, green and purple it resembles a caricature of some sort rather than a graceful

dragonfly. But its stubby, dead white and much wrinkled wings begin to develop immediately so that in a few minutes they have attained their full length of over 2 inches each; they are a beautiful silvery transparent and still held close together over the back, extend beyond the yet rather chubby abdomen. Before very long the abdomen assumes its proper slenderness and length, the wings are suddenly brought down in the familiar horizontal position and soon *Anax,* though not as yet a vigorous insect, is able to fly well enough. Some days elapse before it has acquired its full coloration and a strong flight.

Like other insects this dragonfly has enemies. Its eggs are parasitized by an *Anagrus* wasp (Mymaridae), a tiny insect finally discernible in the *Anax* egg as a reddish form that occupies hardly half of its host (Plate VIII, 52). An adult male *Anax strenuus* taken December 1935 on the Island of Lanai by Mr. R. L. Usinger bears a number of subglobular, six-legged mites crowded on parts of the sternites or underside plates of several abdominal segments. These acari however, probably do little injury to so large an insect. The young *Anax* devour one another, and it is quite probable that frogs eat the insect during the precarious period of transforming into an adult.

The mouth parts of this dragonfly are figured on Plate IX.

Anax junius Drury.

Drury, 1773: Mtk. Cat., p. 105.

The big green darner, as this dragonfly is known on the mainland of the United States, is nearly cosmopolitan in its distribution and quite common in the Hawaiian Islands. A near relative of our giant *Anax strenuus,* it averages about an inch less in wing expanse, and differs again from that species somewhat in the form of the terminal appendages and in having the front margin of the wings pale yellowish, instead of mainly dusky as in *strenuus.* And furthermore, *junius* is rather the brighter hued insect of the two, both as a nymph in its later stages (Plate VII, 42) and as an adult. The male *junius* has the head, thorax and first segment of the abdomen green, the remainder of the abdomen being pale blue and black. The female has the greenish extending to include the second segment of the abdomen, the slender remainder being chiefly a gray brown above with green on the sides of the few terminal

segments. Specimens of this dragonfly that have a wing expanse of 114 millimeters are considered large individuals though not uncommon, while those measuring 110-112 millimeters are frequently met with, and hence it would appear that these Island representatives are of a generally greater size than the same species on the mainland where Needham and Heywood (1929) give its wing expanse as 105 mm., and Seeman (1927) as 107 mm.[14]

While *Anax junius* is often found in the same situations as the endemic *Anax strenuus,* and indeed Dr. Perkins (1913) has several times ". . . taken the male of the one attached to the female of the other . . .", it is an insect more characteristic of the lowlands, where it breeds in reservoirs, rice and taro fields, swamps, and even in brackish water. Adult dragonflies may often be seen patrolling the higher ridges behind Honolulu and they are frequent in and about the city itself, where their voracious nymphs are sometimes a hazard in goldfish ponds. Occasionally the adults are carried to great heights by air currents, Prof. W. A. Bryan recording a specimen taken from an ice water pool at the summit of Mauna Loa, which has an elevation of over 13,000 feet (Proc. Haw. Ent. Soc., III, No. 4, p. 295, 1917).

Alfred Warren in an article entitled "Dragonflies and their Food" (Proc. Haw. Ent. Soc., III, No. 2, pp. 72-82, 1915) gives considerable data of the food of the adult and nymph of *Anax junius* and of *Pantala flavescens* Fabr., the commonest dragonfly here. Adult *Anax junius,* as represented by 24 individuals, were found to have consumed a total of 45 insects (and one mite) representing six orders. The commonest victim was the honey bee, *Apis mellifica* (9 individuals),[15] while of mosquitoes, only 3 individuals were recognized. One damselfly had been eaten and also a single specimen of the dragonfly *Pantala flavescens.* The insect sometimes captures some of the more injurious moths as these are flying about cane fields.

Towards sunset of a quiet and rather warm day in April 1935, the writer observed in Honolulu a number of green darner dragon-

[14] On August 3, 1935, alongside a plantation reservoir at Waianae, Oahu, the writer placed his net over a trio of *Anax junius* struggling together on the ground. Their wing expanses were as follows: 102, 110, and 117 mm. (= 4⅝ inches).

[15] *Coryphaeschna ingens* Rambur, a somewhat larger dragonfly than *Anax junius,* is quite destructive to the honeybee in southeastern United States where it is known as the bee butcher (Needham and Heywood, 1929).

flies flying low over the beach and to some little distance out over the water. They were evidently feeding upon a species of fungus gnat so numerous at the time as to fill the air. The *Anax* flight continued until well past 6 o'clock, when they were observed flying among the tall coconut palms.

Pairs of *Anax junius* may often be seen about lowland reservoirs and weedy swamps, the female dragonfly with her abdomen part ways in the water, inserting her amber yellow eggs (Plate VIII, 50), slightly less than 2 millimeters long, in the stems of various plants in more or less submerged debris, or she may rest on a dense mat of green algae and probe it with the tip of her abdomen. When inserted in the quite slender stems of *Marsilia,* the eggs produce obvious bulges in them. Mainland observations by entomologists give the incubation period as about 3 weeks and the nymphal life as 11 months. It is certain that at least under favorable conditions here, the nymphs develop much more rapidly. Its food is usually abundant here and the water, particularly the shallows, become very warm during the day. Where our lowland bodies of water contain no fish, but teem with such minute Crustacea as Ostracoda, and with bloodworms, *Chironomus hawaiiensis,* the nymph of *Pantala flavescens* and *Megalagrion xanthomelas,* our lowland damselfly, *Anax* thrives exceedingly. In the shallows of a weed-choked pond near the sea, the writer remembers seeing the nymphs of *Anax junius* almost in hordes and in a number of different instars. And where top minnows abound, the aquatic weeds, particularly the mats of algae, afford sufficient cover for *Anax* to breed in some numbers; and when the nymphs are well grown they no doubt venture to attack the smaller fish as well as the tadpoles. A gentleman in Honolulu who kept some goldfish in a pond in his garden complained of the brazen voracity of the *Anax* nymph which would attach itself to a fish swimming by. Observations by Warren (1915) on the nymphs of *Anax junius* and *Pantala flavescens* combined, showed their food to be chiefly bloodworms (*Chironomus hawaiiensis*) and minute Crustacea (*Cypris,* Ostracoda). Mosquito larvae did not figure largely in their menu.

The nymph of *Anax junius* undergoes many moults. In its early life it is conspicuously bicolorous (Plate VIII, 51)—pale yellowish and dark brown; later it is brownish, more or less striped with green and is flecked with darker spots, etc. It is then some-

what more definitely patterned and less dusky than the nymph of *Anax strenuus,* that dwells in generally more shady situations in the uplands. The full-grown nymph of *junius* is about 45 millimeters long. The adult issues under cover of darkness.

A very readable account of the life of the big green darner is that by Needham, J. G., and Heywood, H. B. (A Handbook of the Dragonflies of North America, 1929, on pages 7-10).

FAMILY **LIBELLULIDAE**

Nesogonia blackburni (McLachlan).

Lepthemis blackburni McLachlan, Ann. Mag. Nat. Hist. (5) XII, p. 229, 1883.

Nesogonia blackburni, Kirby, Ann. Mag. Nat. Hist. (7) II, pp. 346-348, 1898.

"Hab. On all the Islands, in mountain forests, or deep valleys, . . . The species is variable in colour, size etc." Perkins, R. C. L., Fauna Hawaiiensis, II, p. 62, 1899.

Like *Anax strenuus* Hagen, our giant dragonfly, this pretty native species is geologically speaking, considered a recent arrival in the Hawaiian Archipelago. Kirby created a new genus for its reception, but Kennedy (1929, p. 979) states that: "*Nesogonia* is so close to the holarctic genus *Sympetrum* of fifty or more species that it could be put in that genus with little argument."

N. blackburni (Plate X, 60) has an expanse of wing of from somewhat less than 3 to about 3½ inches. The wings are for the

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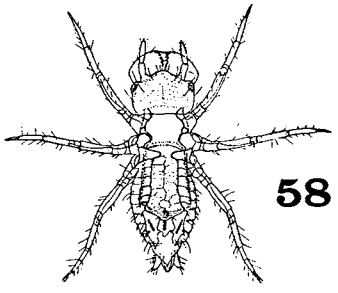
X

NESOGONIA BLACKBURNI

Explanation of Plate

58. Recently hatched nymph, with mask or labium partly extended. Tracheae or respiratory tubes and the dark midgut (containing yolk mass) showing.
59. Three-quarter grown nymph. Among its hairs are *Vorticella* (Protozoa), diatoms and sewage-like bacteria.
60. Adult dragonfly. Expanse of wing a little less than 3 inches.
61. Egg, the day before hatching.
62. Eggs, one day old. 0.54 mm. long by 0.35 mm. thick.
63-65. Rough sketches of developing adult. 63, development at 10:10 p.m.; 64, at 10:35 p.m.; 65, at 10:50 p.m.



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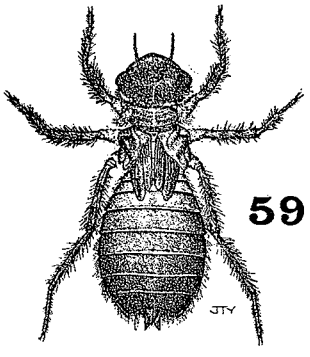

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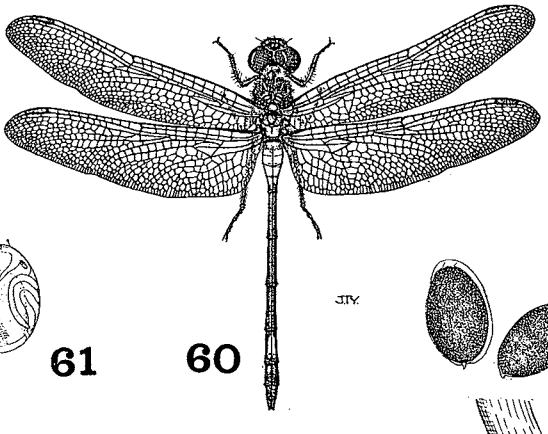

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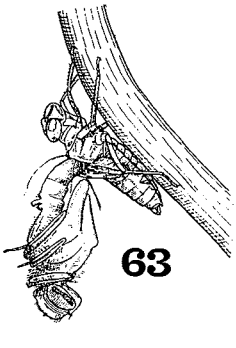

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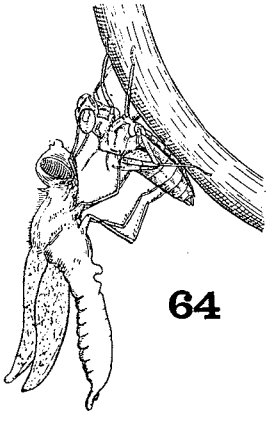

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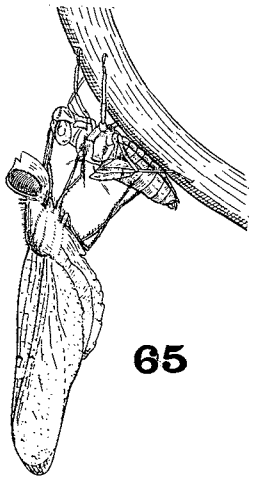


65

Nesogonia

most part nearly transparent, but the stigmal spot is reddish brown, while at their narrowed base there is a little yellowish brown and just before which, at their articulation with the thorax, there is a bit of red. The body is mainly dark, almost blackish, with some yellowish or greenish-yellow dashes on the thorax, a suffusion of reddish at the bulbous base of the abdomen and a long spot of that color towards its slightly clubbed extremity.

Sometimes we may see this dragonfly sunning itself in the middle of or alongside a mountain trail, but it is more usual to find it about small streams, where it perches with outspread though somewhat downbent wings, on boulders, or rocky stream bed, on twigs, leaves, etc., that are on or relatively close to the ground. Watching this insect near at hand, its head will perhaps be seen to move this way and that, as thus with great bulging eyes it appraises passing insects—other Odonata, with which it may quarrel, or small flies to serve it as food. If perchance *Nesogonia* be sufficiently near a swarm of the delicate green *Tanytarsus* midges hovering lazily over the water, it may dart into this swarm, seize a midge, regain its perch and there leisurely chew up the tiny insect.

The egg-laying operations of *Nesogonia* are very simple. She may select a pool in midstream, a small detached one that is becoming stagnant, a clear spring, a thin flowing sheet of water or a puddle choked with weeds. Hovering alertly she dips down and somewhat forward so that the tip of her abdomen strikes the water; she repeats this performance again and again, darts on a little way, selects another spot, hovers and again dips her abdomen in the water. One female was seen to meneuver with clattering wings among a dense growth of *Commelina* plants and occasionally to dip the extremity of the body in this stem-choked puddle. A well worn individual that seemed not to possess much energy alighted in order to lay her eggs, in this case in shallow water. If we capture one of these insects thus engaged in ovipositing and examine the club-like extremity of the abdomen, we would find on its underside a cavity or basket[16] full of pale translucent, yellow eggs, each filled with a granular material. Each of these stout eggs is about half a millimeter long and one-third of a millimeter wide (0.54 x 0.35), as measured in one example (Plate X,

[16] The bursa copulatrix.

62), and one adheres to another to form a mass. If, however, we dip the abdomen in the water, some of these eggs will separate and sink to the bottom. Thus *Nesogonia,* by dipping the extremity of her abdomen with a rather forward movement, in the water, washes the eggs out of her basket and lets gravity do the rest.

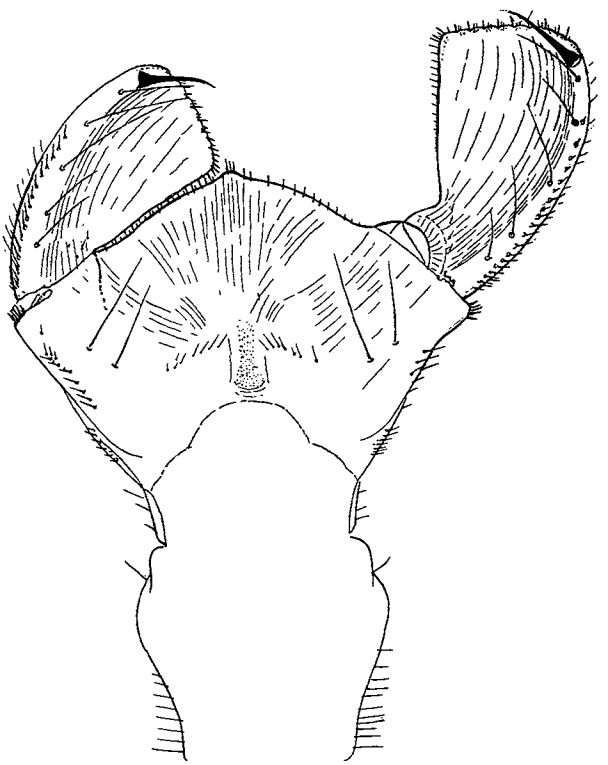


Fig. 1. *Nesogonia blackburni.*
Labium of last stage nymph, from inside.

When in the water, a clear gelatinous envelope is seen to surround each egg. Later on, additional eggs pass into the bursa copulatrix and, in time, oviposition is repeated. The eggs turn a sort of amber yellow and develop rapidly so that in a few days a well advanced embryo with its curved appendages and large yolk mass, is discernible (Plate X, 61). In about 11 to 13 days—in the laboratory—the eggs hatch into sprawling, spider-like nymphs (Plate X, 58, after the pronymphal moult) that soon and without feed-

ing attain about twice the length of a newly laid egg and exhibit through a transparent skin a well-defined respiratory system with paired dorsal and ventral tracheal tubes, connections and branches extending far into the legs and antennae. Visible also is the rather opaque mass of yolk that occupies the mid gut and that supplies the first nourishment to the tiny nymph; all subsequent meals must be earned!

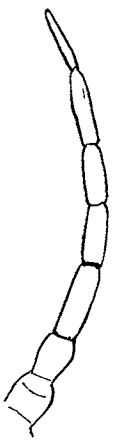


Fig. 2. *Nesogonia blackburni*; last stage nymph. Antenna.

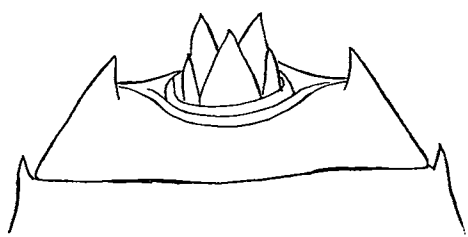


Fig. 3. *Nesogonia blackburni*; last stage nymph. Apex of abdomen.

The nymphal development was not followed through. Many young in various stages of growth were taken from time to time, and adults reared from nymphs captured late in life. It is a very sluggish creature that stays on the bottom, in masses of confervae or on the side walls of pools. It is sometimes seen in company with certain damselfly nymphs in stagnant pools containing mosquito (*Culex*) wrigglers. Particularly in its later stages, when it sheds its skin at longer intervals, it may develop a very unkempt or frowsy appearance, the nondescript brown body then harboring colonies of long-stemmed protozoans (*Vorticella*), while diatoms and clusters of sewage-like bacteria will accumulate profusely among the hairs (Plate X, 59). This shaggy covering of micro-organisms makes *Nesogonia* rather inconspicuous in the water and this would be considered by some to be of distinct advantage to it in the struggle for existence.

The nymph is easily reared, for it is a hardy insect capable of enduring long fasts. Captive specimens will often come to the surface at night and this movement probably occurs in nature as well.

The adult hatches under cover of darkness, and at least under laboratory conditions, the nymph may commence to emerge from the water late in the afternoon. It is now about 23-24 millimeters or a little less than an inch long. For several days it has taken no food and it remains quietly in the water near the surface. At the proper time it crawls up some boulder or other convenient surface, the skin parts along the head and thorax and the soft and swollen adult works through the fissure until its head, thorax and the basal part of the abdomen are free. It is now suspended head downwards, legs folded against the breast (Plate X, 63). The developing insect gives an occasional twitch and at last suddenly bends up and forward and grasping the firmly anchored nymphal shell, pulls itself completely out of this exuviae. Thereafter wings and body develop rapidly (Plate X, 64, 65), and markings appear so that by morning it is ready to essay a flight.

Adults may be seen throughout the year, and no doubt eggs are laid during this entire period.

Pantala flavescens (Fabr.).

Libellula flavescens Fabr. Ent. Syst., Suppl., p. 285, 1798.

This large brown cosmopolitan species (Text fig. 4), is the best known dragonfly on Hawaii. Fraser (Insects of Samoa, Fasc. I, 1927, on p. 41) speaks of it as the dominant dragonfly of the world, while Needham and Heywood (Dragonflies of North America, 1929, on p. 252) further attest its wide distribution when they name it the "Globe-Skimmer". While typically a lowland species, *Pantala* may frequently be seen on the wing well up in the mountains. It is a pretty sight when some dozens of these airy creatures, each shining golden bronze in the late afternoon sun, are patrolling some open space along a country roadside, or in the town itself. And when the shadows lengthen still more, these sociable insects will disband to perch for the night on a convenient vine or bush. These resting places are selected with some circumspection and several of the insects may rest quite close to one another.

The adaptability of *Pantala* to its surroundings and its relatively quick transformations account to some extent for its abun-

dance. The insect seems to lose no opportunity for laying its eggs —this being done on the wing—and the nymphs may at times fairly swarm in lowland marshes, rain puddles, rice and taro fields, as well as in reservoirs. Top minnows must keep it in considerable check where the fish abound, but dense algal growth affords the nymph a degree of protection. Likewise does this insect breed, along with other species, in rock pools left by high water of open streams such as are to be found about the Hilo coast of Hawaii. When occurring in numbers in small shallow pools the nymphs—that can see quite well—form a rather ludicrous crowd as they squirt noisily away in panicky haste at one's approach.

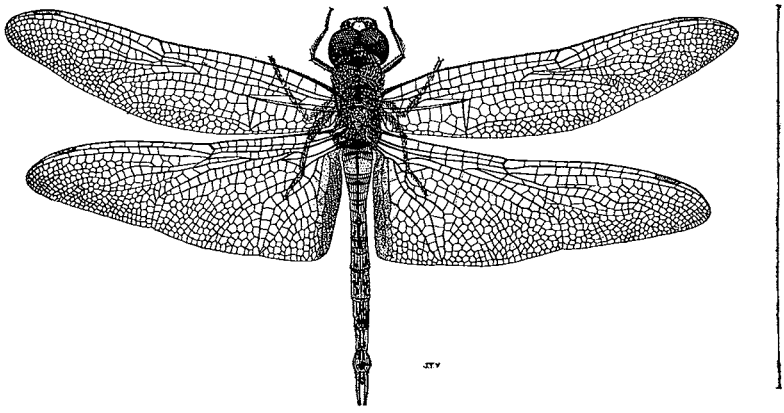


Fig. 4. *Pantala flavescens,* our most common dragonfly. (From "The Insects and Other Invertebrates of Hawaiian Sugar Cane Fields", 1931).

Alfred Warren (College of Hawaii Publications, Bulletin No. 3, Honolulu, October 1915, 45 pages; illustrated) has made an interesting study of the biology of *Pantala flavescens* and to a lesser extent, of *Anax junius.* The female *Pantala* lays a great many eggs—these being deposited freely in the water when she strikes the tip of her abdomen on the surface. Warren secured 816 eggs from a single female. The eggs are whitish at first but turn yellowish later on and measure about 0.33 x 0.20 mm. The incubation period was found to be from 5 to 7 days. Counting the pronymphal state as the first instar, Warren found that there were 11 to 12 instars (10-11 moults). According to the amount of food given them, the nymphal period varied (in 4 examples) from 55 to 101 days. The nymphs—as per dissection of the alimentary

canal of field caught specimens—fed upon a variety of animals—of which insects predominated—these being by far best represented by bloodworms (*Chironomus hawaiiensis*). The tiny clam-like crustacean *Cypris* was a good second. The adults ate many kinds of small flying insects; flies first, and then small moths predominating in an examination of the alimentary canal and mouth parts of 218 of these dragonflies.

The nymph of *Pantala* (Plate XI, 67) is of the "sprawler" type, it is broad and somewhat flattened. When full fed it is about an inch long and considerably resembles the less common *Tramea lacerata* that inhabits much the same situations. From Plate XI, it will be seen however that the *Tramea* nymph has somewhat the wider and more angular head, the abdomen too is perhaps relatively more broad and there is some difference between the two in the spines about the apex of the body. But a front view of the face of these two nymphs shows marked differences—*Pantala* has the broad lateral lobes with strong, deeply incised, saw-like teeth, while *Tramea* has low, and rather poorly defined, rounded teeth (Figs. 68 and 69).

Pantala flavescens is a notable migrant. Robert McLachlan (Ent. Mo. Mag., VII, 254, 1896) in a note quotes from the Meteorological Log of the P. and O. steamer "Victoria", Capt. Worcester, R.N.R., as follows: "April 11th 1896, 11 P.M.—'Numerous dragonflies appeared in chart room and cabin. Nearest land Keeling Island, N. 20 W., 290 miles, N. W. of Australia, S., 70 E., 900 miles.' At the time the wind was moderate from eastward with heavy rain." And F. C. Fraser (Rec. Indian Museum, XXVI, 443, 1924) writing on Odonata of W. India, says of *Pantala flavescens* as follows: "A universal dragonfly found throughout the year. In the Nilgiris, I witnessed two years running, a flight of these insects from North East to South West which lasted for several weeks during the months of September to November. This flight is probably an annual migration and is spoken of by the natives as 'the pilgrimage'."

In Hawaii this insect may fly at least until sunset, and in this connection a further quotation from Major F. C. Fraser, on dragonflies from the Andamans (Rec. Indian Museum, XXVI, 410, 1924) is of interest relative to this species. "It is not uncommon to find this insect adopting crepuscular habits, and concern-

ing the specimens in the present collection, Dr. Annandale remarks —'Flying over open grassy places when the sun has set'."

Tramea lacerata Hagen.

Hagen, 1861, p. 145.

This large, swift flying insect (Plate XI, 66) is easily recognized by the black area at the broad base of the hind wings. This black varies in extent and form with the species of *Tramea,* its jagged or torn appearance well meriting the name of "Raggedy Skimmers" given by Needham and Heywood (1929) to the members of this genus.

Tramea lacerata is well distributed over the mainland of the United States. It is widespread over the lowlands of the Hawaiian Islands but is not particularly abundant. Occasionally we see a specimen flying about Honolulu, but it is more at home over marsh and reservoir in which it passes its early stages.

The subspherical eggs are released freely in the water when the female dips forward the tip of her abdomen in it.

The full grown nymph is about an inch long (Plate XI, 70). It is marked in shades of green yellowish and brown. The compound eyes are more prominent than in its relative *Pantala* and its abdomen perhaps a little wider, while the teeth on the lateral lobes of the labium of *Tramea* are low, and rounded and thus hardly well marked. It swims well by squirting water from the end of its body and by making rapid backwards strokes with the fore and middle pairs of legs, the third pair being held back and somewhat diverging.

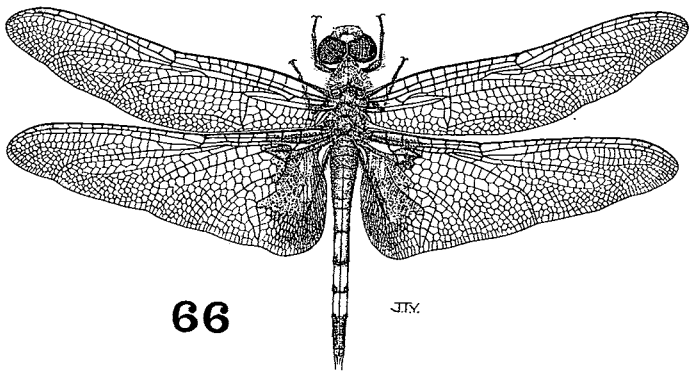
The few nymphs of this insect secured by the writer came from a reservoir at Waianae, Oahu.

XI

Explanation of Plate

66. *Tramea lacerata,* female. Wing expanse 94 mm. or 3¾ inches.
67. *Pantala flavescens,* full grown nymph. Length about 25 mm.
68. *Pantala flavescens,* front view of head of full grown nymph to show well developed teeth of lateral lobes.
69. *Tramea lacerata,* front view of head of full grown nymph to show low blunt teeth of the lateral lobes.
70. *Tramea lacerata,* full grown nymph. Length about 27 mm.

Figs. 66, 67 and 70 drawn from photographs by W. Twigg-Smith.



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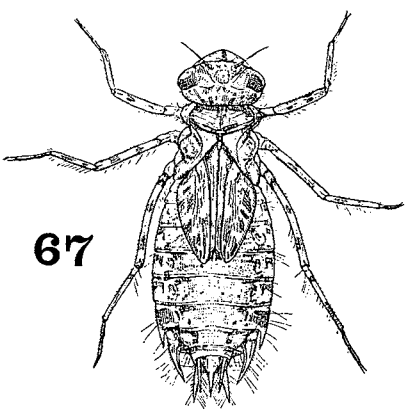

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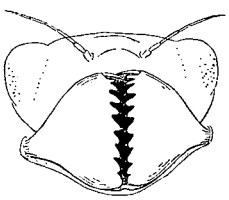

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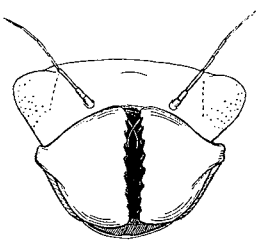

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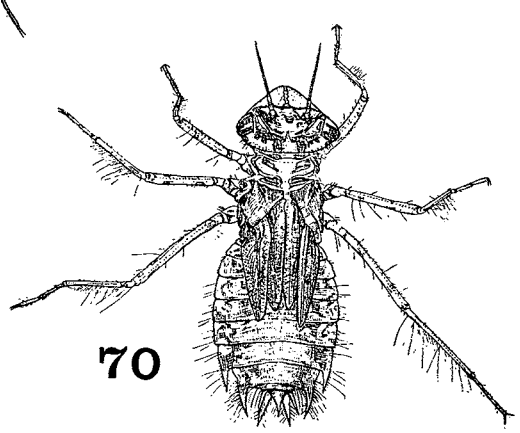

70

Tramea lacerata and **Pantala flavescens**

SUBORDER ZYGOPTERA (DAMSELFLIES)

FAMILY **COENAGRIONIDAE**

The Hawaiian damselflies, some 25 species in number, belong to the supergenus *Megalagrion*[17] and are among our most interesting and attractive insects. All are peculiar to the Archipelago while more than half of them seem to be restricted to particular islands of the group. Probably derived from a single species that reached our shores at a very remote period, *Megalagrion* has undergone considerable evolution so that it is now divisible into a number of subgroups, each of which contains one or more species. These subgroups appear to be founded on characters of the adult insects[18] (McLachlan 1883, Perkins 1910, Kennedy 1920, 1922 and 1929); enough, however, is known of the early stages of Hawaiian damselflies to show that here as elsewhere among the Odonata, a classification based upon the structure and even the habits of the naiads, nymphs or larvae—as the young are variously called —is also possible.

We owe much to Dr. R. C. L. Perkins (Fauna Hawaiiensis, I, Pt. VI. pp. clxxv-clxxx, 1913; II, pp. 63-77, Pl. V, 1899; II, Pt. VI, pp. 693-696, 1910; and Proc. Hawaiian Ent. Soc., I, pp. 50-51 and 93, 1906, and II, pp. 180-181, 1912) for data on the habits, distribution and relationships of our damselflies, and the rather brief notes of Dr. Perkins on these insects indicate that his store of knowledge regarding them is very considerable. Valuable also are his unpublished notes pinned with certain of the specimens.

The adult damselfly is an insect that is almost delicately graceful, with a very slender abdomen (more slender in the male) and two pairs of long narrow wings of nearly equal length held, when not in use, close together or slightly expanded edge on, over the back (Plate XVI, 108). The wide mobile head is provided with great bulging and sometimes beautifully colored eyes (and face)

[17] *Megalagrion* has been subdivided by Kennedy (Ohio Journ. Science, XXI, No. 2, Dec. 1920, on page 86) into three genera, as follows: *Hawaiiagrion,* that includes *deceptor, calliphya, nigrohamatum, vagabundum, molokaiense, microdemas* and others; *Kilauagrion,* that includes *nesiotes,* and *dinesiotes* Kennedy (Ann. Ent. Soc. America, XXVII, pp. 343-345, 1934); and *Oahuagrion,* for the species *oahuense.* Presumably this would leave McLachlan's genus *Megalagrion,* as used in the strict sense, to include the large species *blackburni, oceanicum* and *heterogamias.*

[18] The most convenient of these characters to use are the two pairs of terminal appendages of the male (see Plate XVII) and the mesostigmal plates of the female. The mesostigmal plates, sometimes partly overlapped by the posterior portion of the pronotum are thus situated at the anterior part of the mesonotum (see text fig. 9, for *M. oahuense*).

that are quick to perceive moving objects, while the strongly spinose legs placed well forward may be used as a sort of basket to help capture insect prey and to place it within reach of the jaws. A curved and ensheathed spine-like process, really consisting of four closely-applied pieces (Plate XVIII, 119), very near the tip of the abdomen beneath, of the female, marks the ovipositor, which is finely saw-like on the inner side and thus adapted for cutting slits in plant tissues or other materials for the reception of the eggs. The male is provided with clasping organs at the end of the abdomen, while the copulatory organs are near the base of the abdomen and the genital aperture opens on the 9th segment.

A few of our damselflies may be found near sea level. The majority, however, are forest insects and occur chiefly along watercourses and high ridges, their larvae having been collected at elevations of at least 5,000 feet (Nauhi, Hawaii), while adults extend to much greater altitudes. The smaller species may not be strong flyers, but the larger and more robust kinds of the *M. blackburni* type—the males of which are often conspicuous because of their bright-red color—are quite vigorous on the wing. Damselflies are able to fly backwards. Their bill-of-fare includes many kinds of small insects. It has frequently been observed that they are fond of small moths, which are caught on the wing or when perched. Occasionally they pounce upon flies that may be walking on the ground near their perch, and they devour swarming midges, as do the damselflies on our mainland.[19] On Oahu I once observed a large female damselfly, probably *M. deceptor,* pounce upon a lacewing fly (*Chrysopidae*) that was flying by, settle with it and consume it quite or nearly in its entirety, requiring nearly 55 minutes for this meal. I saw one of the chrysopid's wings crumple up between Megalagrion's jaws. Hardly was the meal finished than it flew up at what appeared to be a sharpshooter bug (*Siphanta acuta* Walker), but finding this too hard or bulky, dropped it. Small aculeate wasps (*Nesomimesa* or *Crabro*) that hovered close before the resting damselfly were not seized by it. Not infrequently they prey upon damselflies smaller than themselves, particularly when these, as freshly emerged individuals invite capture by a weak flight from one point to another. Not all small insects form suit-

[19] Garman, P. (Bull. State Ill. Lab., Nat. Hist., XII, Art. IV, 1917, p. 445) found that adult damselflies consume a great many small Diptera, of which nematocerous flies form a large part.

able food however, for a staphylinid beetle was once seen captured in flight and then rejected as being perhaps, of too hard a texture for consumption. In eating, the broad, somewhat scoop-like lower lip or labium effectively holds the prey from beneath, while the sharp-toothed mandibles and the maxillae chew and pass it along.

In her egg-laying operations the female damselfly may be accompanied by the male, that then holds her in tandem fashion, or she may be quite unattended. She inserts her eggs usually in plant tissues, commonly leaves and stems—green or decayed—in the water, at the surface thereof, or even well above it, and finally, quite away from water. Such eggs, according to species, range in length from about 0.70 to 1.00 millimeter. They are rather tough and quite pointed at the head end, which has a cap of a deeper shade. The operations involved in oviposition often strike one as rather aimless. The damselfly then feels about her with the tip of her abdomen, her eyes apparently serving her not at all, and many a false start may be made and much groping about, before a suitable repository for the eggs is found.

The ovipositors of our Hawaiian damselflies form an interesting study, although more should be known about the egg-laying habits of these insects before drawing very definite conclusions. I have examined the paired median processes (Plate XVIII, 119, M) of a few species. These processes in *M. koelense* and *amaurodytum* race *waianaeanum,* bear relatively large and well spaced tooth ridges. These two damselflies cut slits in the rather hard tissues of the *Freycinetia* and *Astelia* leaf midribs. In *M. xanthomelas* and *leptodemas* these tooth ridges bear a good deal of resemblance to those of the two preceding species. *Xanthomelas* and *leptodemas,* as far as known, cut slits into plant tissues that are often green. The large *M. oceanicum* that oviposits in green tissues—roots and stems—and, I believe, into softer materials as well, has somewhat closer set tooth ridges than in the preceding four species, so also *deceptor* and *hawaiiense,* of which the latter commonly oviposits in soft tissues such as decayed leaf stems. Finally, in *M. oahuense* we also have rather fine and close set tooth ridges. This species was once observed ovipositing, or attempting to, in moist fern trash.

We have found that the eggs of one or more species of our *Megalagrion* that oviposit in such leaves as those of *Commelina*

and *Ipomoea*, are often heavily parasitized by a mymarid wasp, *Anagrus insularis* n. sp. described by H. L. Dozier on pages 175 and 176 of this issue.

The young of our damselflies have not been thoroughly studied and the writer's observations on them are confined chiefly to the Island of Oahu where 8 out of its 11 species were secured.[20] Some of these nymphs are widely different one from the other both in structure and in habitat. Certain species are fitted for a thoroughly aquatic life, others may spend part of their existence imperfectly immersed, as in thin sheets of water; some often wander among wet rocks and debris; there are those that live between the leaf-bases of certain monocotyledonous plants in the moist forests, and at least one species is terrestrial. In the first group are the best swimmers (as observed in *M. leptodemas, xanthomelas, nigrohamatum* and *nigrolineatum*) with a more slender form and leaf-like caudal gills that serve as efficient sculling organs; in the second and third groups are the fair to rather indifferent swimmers (*M. oceanicum, blackburni,* probably *heterogamias* of Kauai, and *hawaiiense*), much addicted to creeping, more robust and with the caudal gills shorter, broadly sword-shaped or dagger-like[21]; and finally in the last group are those that having abandoned the truly aquatic life normal to the young of Odonata, have changed over to rather squat, sometimes tenaciously-clinging, non-swimming forms with short to very short and stout caudal gills (*M. amaurodytum, asteliae, koelense* and *oahuense*). It follows that under these different environments the food of damselfly larvae may consist of organisms living in the water—and, perhaps, some that have fallen into it—of subaquatic species, or of organisms that are purely terrestrial in all stages of their existence. These and other points in the life-history of our damselflies will be brought out in the rather fragmentary observations on the several species that follow.

[20] The sex of the damselfly nymph, at least in its later stages, may be readily determined from an examination of the 9th ventral abdominal segment (Plate XIV, 93). In the male, a pair of thorn-bearing bosses represent the *valvules* of the genital pore, while in the female, three pairs of processes represent the *gonapophyses* constituting the ovipositor.

[21] The nymphs of this group bear a very considerable resemblance to the unknown coenagrionine nymph from the highlands of Hivaoa, Marquesas Islands and described and figured by Dr. James G. Needham. (Marquesan Insects II, B. P. Bishop Museum, Bull. 114, Pacific Entom. Survey, Publ. 7, 1935, on page 168). It has the wide head and general form of *Megalagrion hawaiiense* (McLachl.), while the gills somewhat resemble those of our large species of the *oceanicum* group. The entire lack of raptorial setae in the unknown coenagrionine is to some extent approached in several of our species.

Megalagrion leptodemas (Perkins).

Agrion leptodemas Perkins, Fauna Hawaiiensis, II, pp. 70-71, 1899. One male "Halemano, Oahu, about 2,000 ft.", February 1893.

This is one of our smaller and more slender species. The male has a very red face—below the antennae—part of the thorax is red and the abdomen is red except for the intermediate portion. The female is more soberly colored; the abdomen while reddish at its extremity is for the most part blackish. It is sometimes abundant back of Honolulu, where it was observed in the Hering branch of Makiki Valley, Tantalus, at an elevation of about 1,000 feet. Here is a tiny stream wedged into a steep canyon that is well shaded by great *kukui* or candlenut trees (*Aleurites moluccana* [L.]), and that harbors a generous share of our meagre aquatic fauna. In addition to *M. leptodemas,* we find here also, *M. nigrohamatum* race *nigrolineatum* (Perk.), *M. oceanicum* (McLach.) and *M. hawaiiense* (McLach.), besides our two native dragonflies, the huge *Anax strenuus* Hagen and the smaller, mountain dragonfly *Nesogonia blackburni* (McLach.). The writer found *M. leptodemas* even more plentiful in the Haleauau Stream at about 2,000-2,400 feet in the Waianae Mountains, in May 1935. It sometimes

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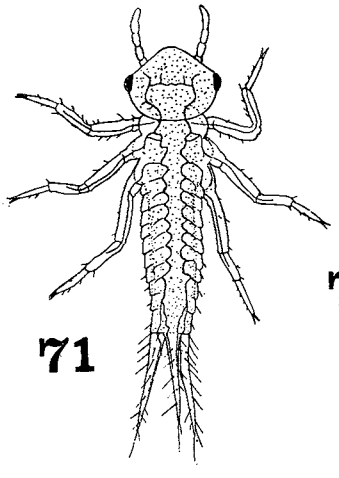
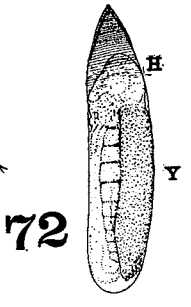
XII

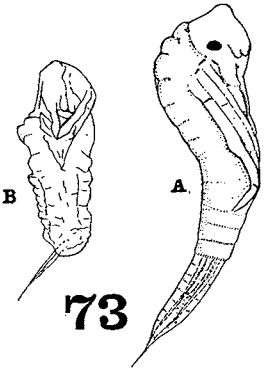
MEGALAGRION

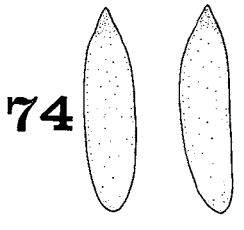
Explanation of Plate

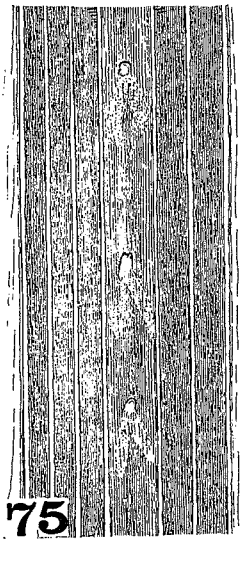
71. First stage following pronymph, of *M. koelense,* or *asteliae.*
72. Egg of *M. koelense,* or *asteliae*: H, head of embryo; Y, the yolk mass. Length 1 mm. Konahuanui, Oahu, 3,000 ft.
73. *M. koelense,* or *asteliae*: A, first or pronymphal stage; B, first or pronymphal moult. Rough sketch. Figs. 71-73 are drawn to same scale.
74. *Megalagrion* sp., two views of an egg of figure 77. Length 0.70 mm.
75. Basal portion of leaf of *ieie* (*Freycinetia*) to show midrib containing 3 egg punctures, each with 2 diverging eggs of *M. koelense,* or *asteliae.*
76. Very young nymph, probably of *M. xanthomelas,* from a lowland marsh. Length 1.33 mm. Probably stage following pronymph. (From Insects and Other Invertebrates of Hawaiian Sugar Cane Fields, 1931).
77. Portion of *honohono* (*Commelina nudiflora*) leaf showing imbedded eggs of *Megalagrion* sp. Hering Valley, Honolulu.

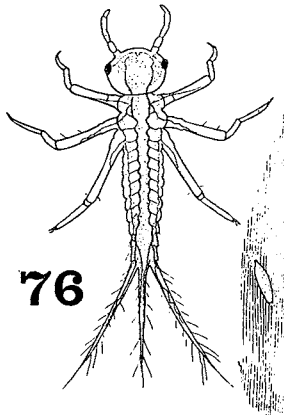


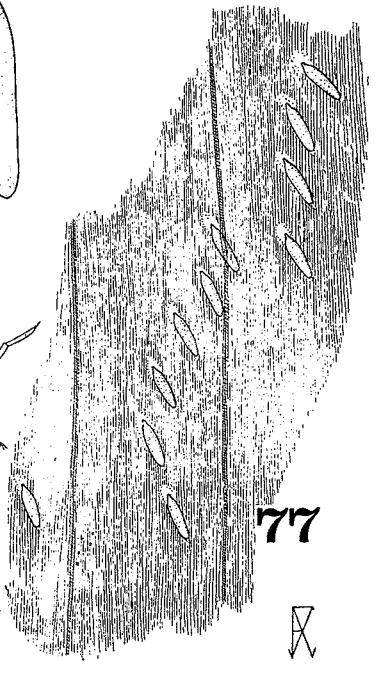












Megalagrion

occurs in the region of straggling rock puddles, at the very headwaters of streams.

At about midday of March 1, 1931, a pair of *M. leptodemas* arranged tandemwise, i.e., the male in advance of, and clasping with the end of his abdomen the fore part of the thorax of the female, was observed at one of the larger pools in Hering Valley. The female was inserting her eggs into a portion of a small leafy twig of a mountain apple or *ohia ai* (*Jambosa malaccensis* (Linn.) P.D.C.) that lay partly submerged in the pool. She spent some time apparently ovipositing near the tip of a rather green leaf, and again at the base of a small decaying bud. Her ovipositor extended just under water. The male attached to her had assumed a rigid upwards position free of any forward support. The twig portion in question was brought to the laboratory and placed in a large jar of water with some algae. On March 12, one or more eggs had hatched,[22] the nymph appearing as the usual glassy, semi-transparent little creature (as in Plate XII, 76) that we find among our damselflies in very early life before differentiation has set in. The antennae and legs are rather short and incompletely segmented while the extremity of the abdomen terminates in three spike-like

[22] It is of course possible that some eggs were laid in this twig prior to March 1.

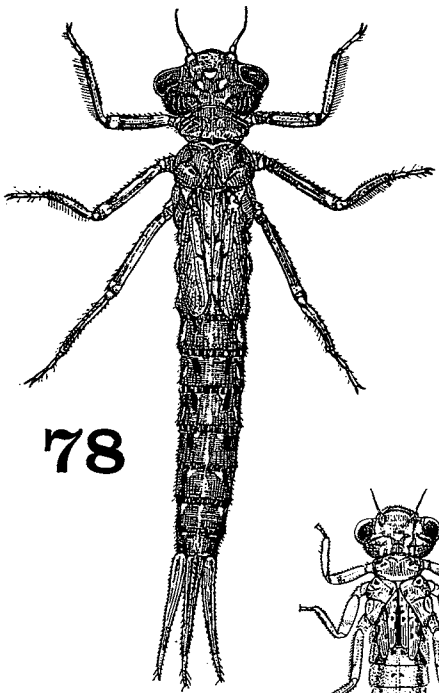
XIII

MEGALAGRION

Explanation of Plate

78. *M. oceanicum,* last stage nymph. The thorax and wings have not yet begun to swell. Length to extremity of gills 21.5 mm.
79. *M. hawaiiense,* last stage nymph near emergence. The thorax and wings have swollen. Length to extremity of gills 15.5 mm.
80. *M. koelense,* or *asteliae,* probably in penultimate nymphal stage. Found at the base of *Freycinetia* leaves. Length to extremity of gills 12.5 mm.
81. *M. leptodemas,* last stage nymph. The thorax and wings have not yet begun to swell. Length to extremity of gills 14.2 mm.
82. *M. nigrohamatum,* last stage nymph. From Molokai, 2,200 ft. It is near emergence and the thorax and wings have swollen. In this specimen the median gill is somewhat aborted and the two lateral ones are represented by dashes. Probable length to extremity of gills, about 18 mm.

Fig. 78 from a photograph by W. Twigg-Smith.



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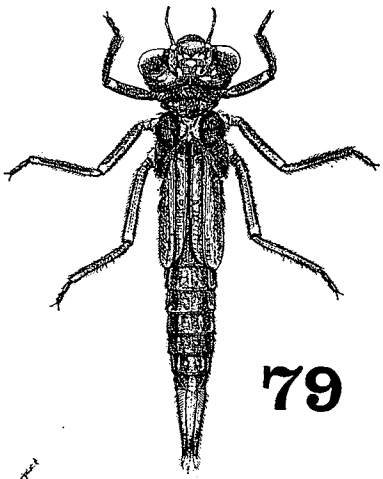

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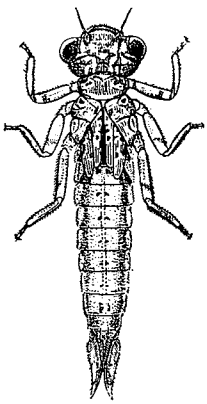

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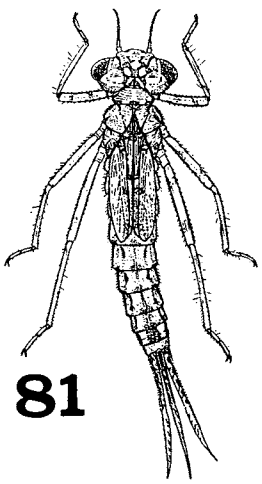

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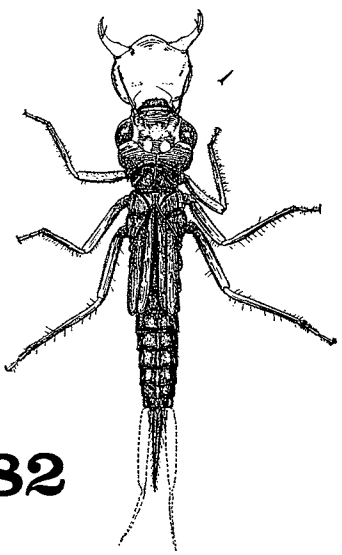

82

Megalagrion

and slightly hairy processes that are about half the length of the body. Longitudinal tracheae or breathing tubes and some of their branches show distinctly in this semi-transparent insect. This newborn though active nymph which we now see is really in the second stage, the pronymph or first stage in the Odonata being of such brief duration—a few seconds to a few minutes—that we are likely to overlook it. The pronymph is somewhat hidebound and pupa-like (Plate XII, 73, A for *M. koelense,* or *asteliae*), the appendages not being free. The young nymph soon commences to feed, snapping up tiny organisms with its extensible lower lip or mask. As it grows it moults from time to time, wings pads appear on the thorax and increase in length, the legs and antennae become more fully segmented, while the three anal gills, at first spike-like, have, moult by moult become beautiful large leaf-like structures (Plate XIV, 91), the median or uppermost of the three being the widest and all showing two axially arranged tracheal trunks pigmented in zones and giving forth delicate, more or less pigmented branches to the margin, the whole producing a tree-like or dendritic effect.[23] These gills appear to be of some importance in respiration—although they are not thus essential[24]—and we often see a nymph swinging its abdomen from side to side as if intent on getting all the oxygen available. Furthermore, they greatly assist in locomotion, for fish-like, *M. leptodemas* sculls swiftly through the water for a short distance. When full-grown it measures about 17-18 millimeters long from head to the tip of the gills. The color is pale wood brown, or more or less grayish green, variegated somewhat zebra-like with darker markings (Plate XIII, 81). The wing pads have attained a considerable length and some of the chief veins are discernible. In due time it ceases to feed, the wing pads now somewhat swollen stand a little apart (Plate XIII, 79, for *M. hawai-*

[23] This type of gill is referred to by Tillyard (1917) as a Vertical Lamella of the Agrionid form, as distinguished from that of the Lestid form. Tillyard makes four subgroups here, showing as many phylogenetic stages in these Agrionid Lamellar gills, which he considers as descended from an original two-jointed gill. The gills of *M. leptodemas* appear to fit well into his third or γ group, the subnodate vertical Lamella, where the originally two-jointed condition is indicated only by a somewhat thicker zone at the base and the outer limits of which are delimited by a slightly different shade and the "stoppng short of the cuticular spines at the point where the node once was" (Plate XIV, 83, A—A).

[24] Dr. C. H. Kennedy (Ohio Journ. Science, XXI. No. 1, Nov. 1920, on page 23) writes as follows: "The primitive method of breathing in the Odonate orders seems to have been rectal because that is the method in the Anisoptera and in the first two instars in Zygopterous naiads. Also any Zygopterous naiad lives normally by rectal breathing after the external gills have been removed."

iense) and we may sometimes see this nymph with the fore end of the body partly out of water. Finally, it creeps up some plant, branch or boulder, the skin of its head and thorax splits above, and the relatively stubby adult, pale and soft, crawls out and rests on or near this nymphal exuviae, the wings and abdomen develop to their proper length and the integument becomes firm and in time assumes the adult coloration. But its first flights on delicate silvery wings are rather feeble and thus often fraught with danger and some time must elapse before it is really a capable flyer.

The single individual, a female, that was reared from the egg stage, developed as follows: Egg laid probably March 1, egg hatched March 12, adult issued June 30, totalling a period of four months.

The nymph of *Megalagrion leptodemas* is thoroughly aquatic, its thin leaf-like gills—which are subject to some variation—precluding any other sort of existence. It lives rather openly in the water, resting on shallow shelving bottoms, on submerged leaves, rootlets or among filamentous green algae. It is common in Hering Valley, dwelling in stream pools and in those which during a dry spell have become cut off from the main body of the stream, thereby affording breeding places for the night mosquito (*Culex quinquefasciatus* Say) and improving conditions perhaps for the larvae of midges (Chironomidae) that so often construct protective tubes upon the old *kukui* leaves that bestrew the water. In one such pool measuring 2 by 4 feet and nowhere deeper than 6 or 7 inches, I counted, from one position, 21 *M. leptodemas* nymphs.[25] Most of these graceful insects were resting lightly and in a more or less horizontal position—except for the rather up-curved abdomen—on old, shallowly immersed leaves. In several instances, the gill tips touched the surface film of water or broke through it.

My few dissections of the crop and gizzard of *leptodemas* nymphs of medium to large size, showed that they fed on mosquito larvae, on the young of midges (Chironomidae) probably mainly *Tanytarsus*—the pale green adults of which are often seen hovering in swarms over the water—and to a less extent on the semi-aquatic larva of one or more species of cranefly (Limnobiidae). In one instance, a copepod crustacean had been eaten. Quite young nymphs probably devour Protozoa and tiny Crustacea.

[25] October 8, 1933.

The nymph of this damselfly greatly resembles that of *M. xanthomelas,* an insect of much wider distribution. In both of these species the setae or bristles on the median and lateral lobes of the labium are better developed than in other Hawaiian species examined (See Plate XVI, 101 and 104).

M. leptodemas appears to be found only on the Island of Oahu.

Megalagrion xanthomelas Selys.

Selys, Synop. Agrionines, légion Agrion, p. 174.

McLachlan, Ann. and Mag. Nat. Hist. (5), XII, p. 232, 1883.

This is another of our smaller damselflies, more stout of form than *leptodemas* and of much wider distribution, probably occurring on all the larger islands. It commonly breeds in stagnant waters of the lowlands and is sometimes found in Honolulu gargens. But it may occur also at higher levels, Perkins (1913) having observed it in Kona, Hawaii, " . . . about stagnant pools up to an elevation of about 3,000 feet." The writer's occasional field studies on this little damselfly were made chiefly at some of the sugar plantation reservoirs of Waianae Company, Oahu, from

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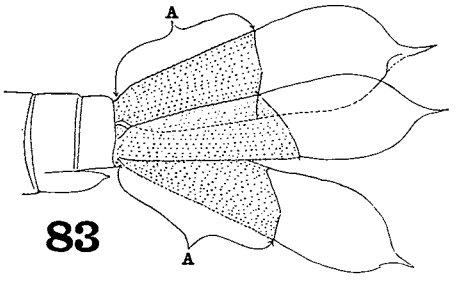
XIV

MEGALAGRION

Explanation of Plate

83. *M. leptodemas,* side view of the three caudal gills. The stippled basal portion at A A represents a somewhat thicker and slightly duskier area. From the Waianae Mts., Oahu.
84, 85. *M. koelense,* or *asteliae,* to show variation in the caudal gills. 84 last, 85 probably penultimate stage. From *Freycinetia* plants in the mountains behind Honolulu.
86. *M. hawaiiense,* median and a lateral caudal gill. Near Honolulu.
87. *M. amaurodytum* race *waianaeanum,* median and a lateral caudal gill. From *Astelia* lily, Waianae Mts., Oahu. There is considerable variation among these gills.
88. *M. oceanicum,* caudal gills.
89, 90. *M. xanthomelas*: 89, median, 90, lateral caudal gill. Waianae lowlands, Oahu.
91. *M. leptodemas,* median and a lateral caudal gill. Near Honolulu.
92. *M. nigrohamatum* race *nigrolineatum,* median and a lateral caudal gill.
93. *M. xanthomelas,* extremity of two nymphal skins from which adults have issued; female and male. The ovipositor sheaths of the female show at A, while the valvules of the genital pore of the male show at B.



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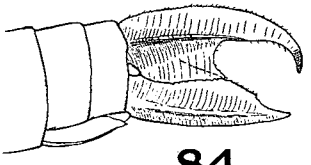

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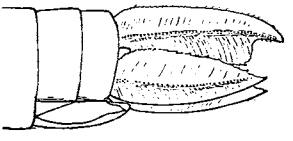

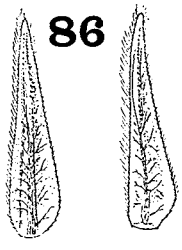

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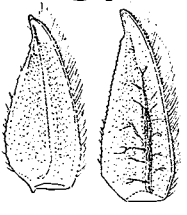

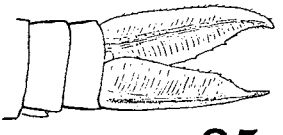

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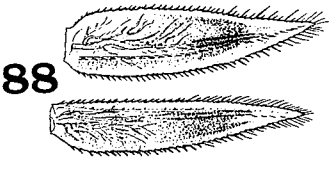

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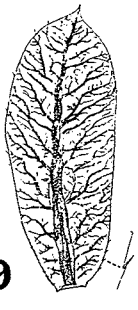

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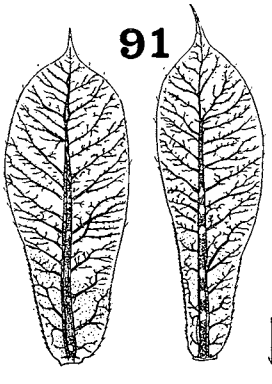

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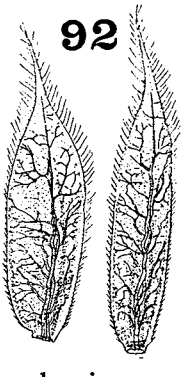

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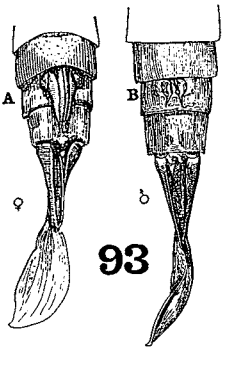

93

Megalagrion

February to April, 1935. These reservoirs, particularly when containing no fish (top-minnows) harbored a considerable number though not a great variety of aquatic and semi-aquatic insects and of other small organisms. And where these bodies of water abounded in fish, a dense covering and flooring over certain areas, of green algae furnished a fair shelter from these fish for much aquatic life. One newly-filled reservoir, then without noticeable water-plant growth, contained many drowned and decaying sedges (*Cyperus*) from the more or less submerged stems and heads of which waved gracefully with the ripples the short, pale brown, gelatinous egg-strings of the common mosquito-like midge, *Chironomus hawaiiensis* Grimshaw. The hundreds, or probably thousands of such egg-strings soon produced a myriad tiny larvae that, sheltering themselves in stationary tubes of mud and debris spun together, increased in size and assumed their blood-worm appearance. These midge larvae, sometimes with those of a smaller midge species and the larvae of *Culex* mosquitoes, together with other organisms such as minute Crustacea—the swift jerky little tailed Copepoda and the active chubby clam-like Ostracoda—constitute in very great measure the food of the larger aquatics—*Pantala, Tramea* and *Anax* dragonflies and of our little damselfly, all quick to take advantage of these waters of plenty. Sometimes we see the savage larva of *Rhantus pacificus,* our largest water beetle—though of modest size—in the cement outlets or adjoining pools, while nearly everywhere along the shore or on mats of algae are small surface-running bugs—*Mesovelia* and *Microvelia*—active, watchful and rapacious. *Microvelia* is known to be quite destructive to tender insects that float on, or issue from the water. *Mesovelia,* a good deal larger, is likewise predatory. Common also on alga mats, slower and less aggressive, though frequently attempting short flights, is the tiny *Merragata* bug. The back-swimming *Buenoa* bug of predacious habit generally keeps in companies some little distance beneath the surface of shaded waters and maintains its position there by an occasional stroke of its oar-like hind legs, while back up on the muddy bottom, a trichocorixid bug, a lover of alkaline waters and probably chiefly a vegetarian, is to be found. The alert brown anthomyid fly *Lispa metatarsalis* Thomson of lowland and upland, is carnivorous and common here on shore or alga mat, while the lank, pale gray dolichopodid fly *Hydrophorus*

pacificus Van Duzee frequents the muddy shore or performs actively upon the surface film.

Such a *biota* or animal association, but incompletely sketched here, fluctuates for better or for worse, in the struggle for existence among its members and, with the introduction into its waters of such active and voracious feeders as mosquito fish, suffers greatly. And thus our lowland damselfly may be numerous or uncommon here as conditions are favorable or adverse to its existence. It can to a degree however, cope with difficult conditions. It is a low flyer and while skimming over the water is not liable to capture by its larger relatives, the immigrant dragonflies that fly higher.[26] It lays a large number of eggs, of which perhaps, the more exposed ones may suffer parasitism by a tiny wasp. Finally, the habit of the nymph of resting quietly among the green algae *Potomogeton* and other fine water plants that it so often resembles in color, affords it a measure of protection.

The adult damselflies could be seen in numbers in April at a certain fishless reservoir, along the shallows of which were more or less immersed plants of the succulent *honohono* (*Commelina nudiflora* Linn.) and of the more plentiful *Marsilia villosa* Kaulf. (*Rhizocarpeae*), a curious little herb with slender petioles terminating in several ribless leaflets that resemble somewhat those of a clover or of an oxalis. Female damselflies in tandem with their mates were inserting eggs—one for every puncture—into these plants. In the several cases observed the eggs were laid a little beneath the surface of the water, one female pushing her abdomen therein for full three-fourths its length. During oviposition the male, retaining with his terminal claspers his hold on the thorax of his mate, grasps with his legs the leaf or stem that extends above or beyond her or, where such support is lacking, assumes a rigid upright position, and may then occasionally flutter his wings in support. The eggs were found imbedded in the slender petioles of *Marsilia* and in the stems of *Commelina*. They are but shallowly inserted and lie almost parallel to the plant surface and are quite frequently exposed at their darker, pointed head end for full one-fifth of their length, the insertion hole being large. When the egg

[26] Needham and Heywood (A Handbook of the Dragonflies of North America, pp. 21-22, 1929) show that dragonflies and damselflies fly at different levels—". . . the big darners highest, the little blues lowest . . ." Thus, the smaller, weaker kinds are much protected from aerial attack by their low flight.

is in the thin *Commelina* leaf it produces a bulge on the upper and lower surfaces. A number of eggs may be laid at one time; they are not without order, all pointing in the same general direction and, when inserted in a leaf, the aggregate produces a sort of wide, stream effect. The egg is fairly stout, about 0.98 millimeters long, and except for the dusky pointed head end, a sort of pale amber color. The same plant stems or petioles that harbor these *Megalagrion* eggs, may also contain the eggs of the large green darner dragonfly *Anax junius* of the lowlands.

M. xanthomelas eggs laid in plant tissue on February 17—and possibly earlier—produced on March 9, tiny, nearly transparent nymphs bearing the usual three long and thinly hairy, spike-like caudal gills (as in 76, Plate XII). No such young were reared through to maturity, but a number of the nymphs of various sizes were secured, chiefly among green water plants. Many of these nymphs were of a greenish color—while others—that may have been in a different environment were dark brown to almost blackish. They are excellent short-distance swimmers. Of somewhat stouter form than *M. leptodemas,* the pigmented caudal gills are comparatively shorter and broader particularly towards the base (compare Figs. 89 and 90 with 91, Plate XIV). In addition, *M. xanthomelas* has the better developed setae on the median and the lateral lobes of the labium, of the two (Plate XVI, 104). A full-grown *xanthomelas* nymph measures about 18 millimeters long to the extremity of the gills.

Seventeen *xanthomelas* nymphs were taken out of a reservoir teeming with top-minnows, but affording some protection to

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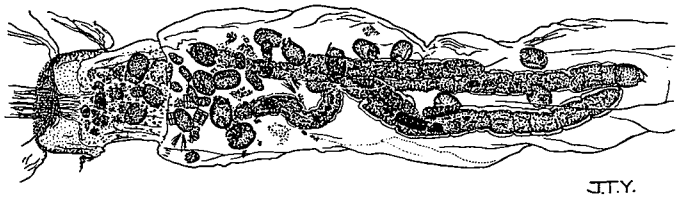
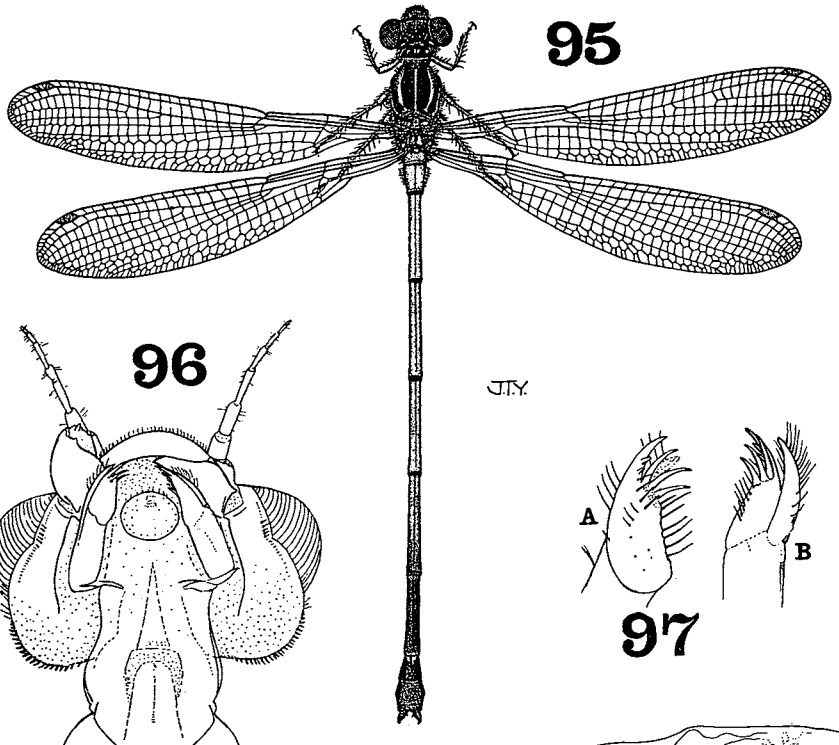
XV

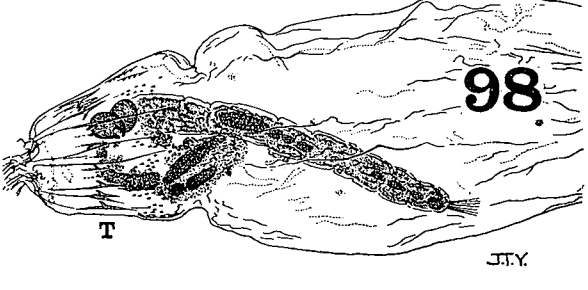
MEGALAGRION

Explanation of Plate

94. *M. oceanicum,* gizzard and crop of a nymph containing remains of numerous *Tanytarsus* midge larvae.
95. *M. oceanicum,* male. Wing expanse 58 mm.
96. *M.* probably *blackburni,* penultimate stage nymph, showing underside of head with labium pulled back. The mental setae are not indicated. Akaka Falls, Hawaii.
97. A and B, Two views of maxillae (in part) of Fig. 96.
98. *M. oceanicum.* Gizzard and crop of a nymph containing remains of *Tanytarsus* midge larvae. At T, are teeth of the gizzard.







Megalagrion

smaller creatures in the dense growths of the green *Enteromorpha* algae. The alimentary tracts of these nymphs were dissected to find out what had been eaten, but as is usual among our damselfly nymphs, the findings were not very satisfactory. Some of the gut contents could not be identified. However, three had remains of nematocerous fly larvae, probably Chironomidae, three others had eaten 2, 2 and 1 oribatid mites, respectively, another contained what appeared to be part of a fly pupa, while the remaining 10 revealed some fine unrecognizable material, or were practically empty.

Several adults were reared from last-stage nymphs—two of these issued at about the noon hour, while a third one came out a little before 3:00 P.M.

XVI

MEGALAGRION

Explanation of Plate

99. *M.* probably *nigrohamatum,* underside of head of nymph. The mentum or free end of the "mask" or labium covers almost the entire underside, a small portion of the cheeks or genae and eyes being visible. From East Molokai Mts.

100. *M. nigrohamatum* race *nigrolineatum,* last stage nymph. The head is in a slightly different position from Fig. 99.

101. *M. leptodemas,* last stage nymph. Underside of head with mask unfolded. ms, setae of median lobe; ls, setae of lateral lobe. Near Honolulu.

102. *M. hawaiiense,* last stage nymph, underside of head. Near Honolulu.

103. *M. amaurodytum* race *waianaeanum,* last stage nymph, underside of head. From *Astelia* lily leaf bases, Mt. Kalena, Waianae Range, Oahu.

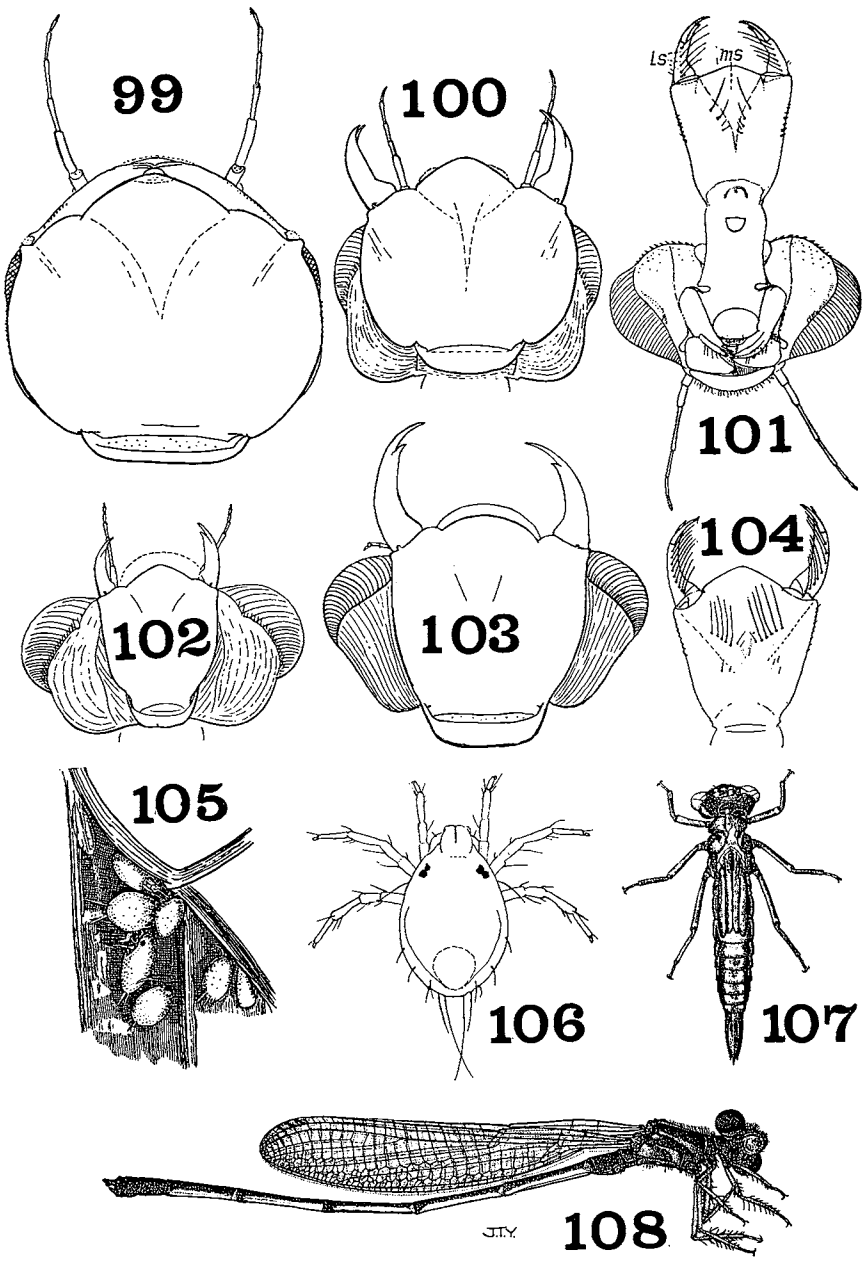
104. *M. xanthomelas,* last stage nymph, to show inner side of mentum of labium or "mask" bearing setae of the median and of the lateral lobes. Lowlands of Waianae, Oahu.

105. *M.* probably *nigrohamatum,* nymph, showing portion of wing pad base infested by young water mites. East Molokai Mts.

106. Water mite from Fig. 105, more enlarged.

107. *M. amaurodytum* race *waianaeanum,* nymphal shell from which adult (Fig. 108) has issued. Length 17.25 mm. Mt. Kaala, Oahu.

108. *M. amaurodytum* race *waianaeanum,* male. Issued from nymphal shell of Fig. 107. Length 42 mm. Ex *Astelia* lily.



Megalagrion

Megalagrion nigrohamatum (Blackburn).

(Ann. and Mag. Nat. Hist. (5) XIV, p. 415, 1884, and the race **nigrolineatum** Perkins, Fauna Hawaiiensis II, p. 65, 1899.

In the typical form *M. nigrohamatum* from Maui and Molokai, the knees of the legs are black, while in the race *nigrolineatum,* from Oahu and itself on the average a smaller insect, there is in addition, a black line along the upper side of the femora. Dr. Perkins' observations on this insect (Fauna Hawaiiensis II, p. 65) are very apt and are as follows: "The bright yellow face and the colour of the eyes, which are bright green or turquoise blue on the lower half, and red on the upper, give this species a most remarkable appearance when flying around streams. The colour of the eyes fades after death."

This insect is one of our common species and is to be seen along streams from near sea-level to 2,400 ft. or more, above. Males and females are frequently observed in tandem, the female having then been noticed inserting her eggs—or attempting to—in plant tissue in running water, and I suspect that she also lays eggs unattended and that she places them above water as well.

On East Molokai at an altitude of about 2,000 ft., what certainly must have been the nymph of this *Megalagrion* was abundant in the clear and cool waters of the Moaula stream and one of its tributaries. Here in late November 1933, the dull brown nymphs could be found clinging to the lower sides of stones that were more or less submerged and, by suddenly lifting up such stones, could be captured. In the Hering and Haleauau Valleys, Oahu, nymphs of the race *nigrolineatum* could likewise be found under stones but occurred also among masses of algae in running or in quiet waters. This nymph then, favors a concealed existence, its rather squat form suggesting a certain environment. It is noticeable chiefly for its large brown head—with the usual pale ocellar marks —and the particularly wide labium, the terminal or exposed underside of which, of a rich brown color is in striking contrast to the paler underside of thorax and abdomen. This folded labium when viewed from beneath, conceals almost the entire head (Plate XVI, 99 and 100).

The lateral lobes each bear a single good-sized bristle, or more rarely, an accompanying small one. The three caudal gills are not so leaflike as in the preceding two species; but form nevertheless

efficient swimming organs. They are long, relatively hairy (Plate XIV, 92) and while definitely 4-angled, tend to be soft, swollen and sac-like for a large part of their length, and somewhat flexible and wrinkled for their slender distal portion. The two entering tracheae of each gill are rather well apart, right and left, for some distance.

If one of these nymphs be placed again in water it will quickly swim to some object and flatten itself thereto.

The very few dissections of alimentary tracts of *nigrohamatum* nymphs from East Molokai (November 1933) showed that they had fed largely on the larvae of chironomid flies of the *Tanytarsus* group. One had eaten what appeared to be a small lepidopterous case-bearer together with a portion of its case. Near Honolulu a specimen in an upland pool containing *Culex* mosquito larvae had devoured some of these.

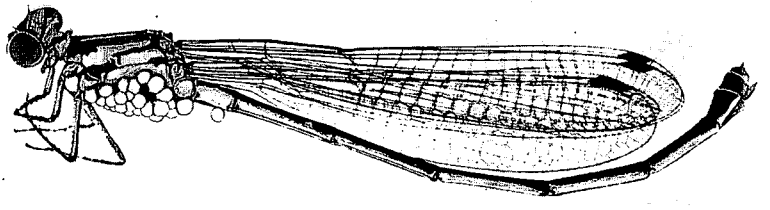


Fig. 5. *Megalagrion* sp., female with thorax and base of abdomen infested with mites or acari. Mountain View, Hawaii.

Clustered about the wing bases of one of these nymphs from the mountains of East Molokai were a number of six-legged mites (Plate XVI, 105 and 106) very much suggesting young *Arrhenurus* (Hydracarina). Of *Arrhenurus* sp., Garman, P. (Bull. Ill. State Lab. XII, Art. IV, pp. 441-442, 1917) writes the following on mainland species: "A mite, *Arrhenurus* sp., is a common external parasite of the nymph. At the time of emergence of the adult, the mite migrates from the nymph to the adult and is carried about by the latter until it is nearly mature, when it escapes again

into the water for the final stage." Text fig. 5 shows an adult *Megalagrion* species, collected at Mountain View, Hawaii, well loaded with closely packed subspherical mites of a brown color. Such mites have also been found on *M. blackburni* collected on Maui (P. H. Timberlake), and on *M. calliphya* collected on Lanai (R. L. Usinger), and they occur also on *Anax strenuus* (R. L. Usinger). Worthy of note here is a paper by Campion, F. W. and H., entitled: "Notes on Dragonfly Parasites (Larval Water-mites, Entomologist, 42, pp. 242-246, 1909).

Megalagrion oceanicum (McLach.) (Ann. and Mag. Nat. Hist. (5) XII, p. 239, 1883). One male, "Oahu at no great elevation above the sea".

Mr. R. McLachlan (1883) in characterizing the genus *Megalagrion,* writes the following, pp. 237-238: "I have established this division for the reception of two of the most magnificent species of the Légion Agrion hitherto discovered". The species referred to are *M. blackburni* and *M. oceanicum* (Pl. XV, 95 ♂). Later, Perkins (1913) added a third species, *M. heterogamias* from Kauai to the group. These are our largest damselflies and the most conspicuous. They often measure three inches or more across expanded wings and the males and sometimes the females are very striking because of the bright red color of the abdomen. They are certainly among the first insects to be noticed by the casual observer who chances to wander about woodland streams; and in the water itself I have found that the nymph *M. oceanicum* is usually the dominant species.

The female *M. oceanicum* usually in tandem, inserts her eggs in the leaves, stems or roots of plants growing in or very near the water. The plants observed to be thus utilized by this insect were *honohono* (*Commelina nudiflora*) and the moon vine (*Ipomoea bona-nox* L.).[27] Eggs recently inserted are inconspicuous, but the puncture scars soon admit decay so that the leaf or stem assumes a densely freckled appearance. The writer recollects in Hering

[27] Other plants so used by forest-stream damselflies on Oahu are, Job's Tears (*Coix lachryma-jobi* L.), *taro* (*Colocasia antiquorum* Schott, var. *esculenta* Schott), the tender tip of a young banana (*Musa*) leaf, and a species of ginger (Zingiberaceae). In the foliage of *Commelina nudiflora* (Plate XII, 74 and 77) and *Ipomoea bona-nox* damselfly eggs may be found literally in thousands though often very heavily parasitized by a tiny *Anagrus* wasp. The identity of these eggs other than being those of damselflies, was usually not determined; the writer believes however, that they were mainly those of *M. nigrolineatum* and *M. oceanicum.* Since these half dozen species of plants are usually regarded as having reached the Hawaiian Islands within historic times, it would be interesting to speculate on what native plants served as repositories for our damselfly eggs in ancient times.

Valley,[28] a tiny and shallow rapids tressed almost mat-like with the parallel rootlets of the moon vine that, extending along the rocky bed of the stream, united to ascend as a cord-like liana, a great *kukui* tree, to leaf out high up among the branches. Three pairs of *Megalagrion oceanicum* were perched on and about these more or less submerged rootlets laying their eggs. Some of these rootlets upon being pulled out and examined, were found to be literally crammed with damselfly eggs easily discerned through the semi-transparent tissues. Ovipositions of an earlier period were visible from a distance of several feet as brownish spots or blotched areas on the rootlets. At another date, a female *oceanicum,* likewise in tandem, was observed rapidly placing her eggs in the upper surface of a *Commelina* leaf above water. Here the time intervals between egg insertions were as little as six seconds.

The young nymphs, on emerging from the eggs if not already in the water, ordinarily make their way into it.[29] They appear to develop rather slowly although the characteristic caudal gill pattern, i.e., a dark blotch before their pale tip (Plate XIV, 88) is apparent when the nymphs are quite young. As they increase in size, these gills become somewhat wider and finely saw-edged and fringed with bristle-like hairs that become longer towards the tip of the gills. These gills are tough and never develop into the efficient leaf-like sculling organs characteristic of the species already discussed. And here for the first time we have a damselfly that while always keeping very moist, often ventures out of water —a habit which does not favor delicate gills. *M. oceanicum* and its relative *M. blackburni* of Hawaii, Maui, Molokai and Lanai, and no doubt *heterogamias* of Kauai, are moderately good swimmers, although their sturdy form seems better suited for creeping among rootlets, algae, in steep running water, shallow pebbly bottoms, up a dripping bank or among stones, under dead leaves in water and in little pockets of water at the bottom of a gentle waterfall.[30] And thus indeed *M. oceanicum* lives under such varied conditions. When quite small it is often found among algae and diatoms in shallow running water, but large individuals may sometimes be

[28] October 1, 1933.

[29] However, Mr. O. H. Swezey has collected *Megalagrion* sp. eggs in *Datura* leaves that were quite far removed from water at the time, so that the emerging young would surely perish.

[30] Perkins (Fauna Hawaiiensis, Introduction) has found *M. heterogamias* P. among wet decaying leaves, and *M. oceanicum* "in wet moss on rocks in stream beds".

disturbed, filmed over with water, several feet up a rock bank and alongside swiftly running water, or lodged in little chinks or notches there. The food of the nymph consists of the larvae of the lower flies of the families Chironomidae, Ceratopogonidae and the subaquatic Limnobiidae, with an occasional Ephydridae and other small creatures. Among the green algae (*Cladophora,* etc.) in or alongside small rapids and falls, the prey may consist of the ceratopogonid *Dasyhelea hawaiiensis* MacFie the larvae of which are orange colored and snake-like, the larva of *Tanytarsus* the little green midge, with an occasional larva of the dusky and erratic *Telmatogeton* (= *Charadromyia*) fly.[31] Where the damselfly nymphs frequent wet rocks, the larvae of crane flies (Limnobiidae) form an important part of their menu. Figures 94 and 98, Plate XV, are drawings from stained slide mounts of the crop and gizzard (showing the gizzard teeth in Fig. 98, T) of two nymphs of *M. oceanicum,* from Hering Valley, Honolulu. The crop and gizzard of Fig. 98, T, are seen to contain as recognizable food, two heads and most of the body, including the hair tuft at the tail end, of the larva of *Tanytarsus* (Chironomidae) ; in Fig. 94 twenty-eight heads and several bodies of these *Tanytarsus* are recognizable. Occasionally a smaller damselfly nymph falls a victim to *M. oceanicum* and *blackburni,* and in the crops of the former a small moth caterpillar, collembolous insects and oribatid mites have also been found. Tiny crustaceans must also be included in the bill-of-fare of these insects, and occasionally an adult water-loving fly such as a dolichopodid, or a little ephydrid fly (*Scatella*) is devoured. In the clear shallow current of a stream back of Honolulu, the writer once saw a large nymph of *M. oceanicum* devouring a small earthworm (*oligochaete*) at the other extremity of which a second though quite small *Megalagrion* was holding fast. A rather small *M. oceanicum* nymph, taken from a dripping wet bank, well browned with water-soaked diatomaceous plants, in the Waianae Range, Sept. 16, 1933, was found to have eaten a small larva of the common water beetle, *Limnoxenus semicylindricus* (Sharp).

M. oceanicum may be easily reared and studied in a shallow dish partly filled with water containing a few dead leaves, some

[31] On East Molokai remains of an adult *Telmatogeton* fly were found in the crop of *M. blackburni,* a close relative of *oceanicum.*

algae and a *Commelina* plant stem. A large specimen which was secured near Honolulu in August, 1933, moulted at the surface of the water on the afternoon of August 12, and when first seen thereafter, was a yellowish or creamy white except for the dark eyes. It seemed more nocturnal than diurnal, sometimes appearing in the evening partly exposed at the surface of the water where it lay atop some debris, or it crawled up a stick so that its head was out of water. It was easily fed by means of tweezers, and when mosquito wrigglers were thus offered it, did not hesitate to snap them up, consuming nine such in rather quick succession. Late in the afternoon of Sept. 8, when this *oceanicum* lay on some litter near the surface of the water and its back well exposed to air, I fed it with the forceps some larvae and pupae of mosquitoes. At the sight of these tidbits it became quite excited, made a short jerky run at a proffered morsel and, upon my gentle drawing away of the latter, was induced to leave its horizontal position and clamber up a stick until quite out of water, and then to seize the young mosquito held before it. Later on this dusky nymph refused food and could be seen clinging to an erect stick, so that only the tips of the wing cases reached the water. On September 19 or 20, it crawled to about 3½ inches above the surface and hatched into an adult. Thus, the time between the moult into the last nymphal stage and the moult into the adult insect, was about 5½ weeks.

Comparing the larva of *M. oceanicum* (Plate XIII, 78) with those of other Oahuan species, we note that this variegated dusky brownish, or more or less olive greenish insect, apart from its larger size—up to 25 mm. long to the extremity of the gills—and the form of the gills, has a relatively narrow head. The labium is wide, its lateral lobes bear usually two small bristles on their inner side near the apex and there are some quite small bristles about the middle inside surface of the median lobe.

The adult *M. oceanicum* and *blackburni* are, among insects, rather bold and aggressive. *M. oceanicum* perched on a particular twig or rock portion in the canyon, darts out from time to time at some insect and quarrels with its damselfly neighbors. It will engage in a scuffle with the dragonfly *Nesogonia blackburni,* a larger and more powerful insect, but sometimes it falls a victim to *Anax strenuus,* the watchful and swift flying giant dragonfly that easily snatches it out of the air.

Megalagrion hawaiiense (McLachlan).

Agrion (?) *hawaiiense* McLachlan, R., Ann. and Mag. Nat. Hist. (5) XII, pp. 232-234, 1883. "Oahu, at no great elevation above the sea."

Agrion calverti Perkins, R. C. L. Fauna Hawaiiensis, II, Pt. VI, pp. 694-695, 1910.

This is a damselfly of medium size that is largely metallic green in color, there being also some pale yellow on the thorax and very narrow bands of that color on the abdomen. A reared male from the Waianae Mts. has a good deal of yellow on the abdomen. It inhabits the canyons of both mountain ranges of Oahu, where I have found it at an elevation of from less than 1,000 ft. to nearly 4,000 ft. above the level of the sea.

Most of the field studies on this insect were made in the well-shaded Hering Valley, Makiki, in the hills immediately behind Honolulu. Ovipositions were noted in March, 1931, and particularly in May 1935, when the bright-hued flowers of the Mountain Apple or *Ohia ai* (*Eugenia malaccensis* Linn.) were clustered about the branches, or here and there as fallen stamens, littered the ground with a thin magenta carpet. Of the dozen female *hawaiiense* observed as being thus occupied, none was accompanied by a male. Eggs were inserted in a decayed, water-soaked leaf midrib that lay in exceedingly shallow water just above a wet rocky bank on which nymphs of *M. hawaiiense* and *M. oceanicum* were often found; another female probed some dead vegetable tissue in shallow running water, and two others likewise investigated wet moss alongside. A specimen of what appeared to be also *hawaiiense* inserted a few eggs within about an inch from the wet ground, in the delicate little stem of a seedling plant. A few *hawaiiense* eggs dissected out of a decayed leaf midrib measured 0.85 millimeters in length. None was reared through to maturity, but from time to time numerous *hawaiiense* nymphs of various ages were collected and a series of adult damselflies reared from wellgrown nymphs. These nymphs are of particular interest since they may be largely terrestrial in habit, although very young individuals were not seen out of a water film. They are comparatively indifferent swimmers, as their dagger-shaped tail gills (Plate XIV, 86) would indicate Specimens may be a generally dark brown color, with the usual lighter spots on the head, and obscure bands on the legs, a pale

area atop the thorax, some marks on the abdomen and the tail gills with a more or less well-defined dark area before their pale tips, or the insects may be largely paler wood brown, that shade being particularly noticeable on the thorax and dorsal part of the abdomen. Mature nymphs are up to 18 mm. long to the tip of the caudal gills, and they somewhat suggest tiny rough-coated lizards (Plate XIII, 79).

A favorite haunt of these nymphs in Hering Valley behind Honolulu, was a steep little rocky bank that, except in very dry periods, remained constantly wet from a very small flow. The face of this bank, more or less irregular, and with here and there some fine aquatic vegetation, was also a breeding place for two species of crane flies, the larvae of which dwelt in spun tubes, in cracks, or under dead leaves, for the little speckle-wing *Scatella* flies and from time to time, for the tiny *Forcipomyia ingrami* midge. Stolid *Scatella* sometimes perched in numbers on this wet bank, and nimble little dolichopodid flies explored the slope. Active staphylinid beetles (*Philonthus haddeni* Bierig)[32] ran about or were concealed under leaves. Above and below, were tiny shallow depressions containing water and plant debris, largely *kukui* twigs and leaves. These rock-creeping *Megalagrion* nymphs were to be found exposed on the face of the rock, squat upon a shining water-soaked bed of brown diatoms, among wet debris, and under old *kukui* (*Aleurites moluccana*) leaves. Sometimes a moist nymph would be standing free of any water film, or its form would cause a hump in a very thin sheet of flowing water. The large *M. oceanicum* also shared this environment, but it is a definitely more aquatic insect. Both *hawaiiense* and *oceanicum* may occasionally be seen in mild sunlight with or without a thin sheet of water enveloping them. A *hawaiiense* nymph in the penultimate stage was secured on the wet rocky bed of a very steep little ravine beside the peak of Olympus, near Honolulu at an altitude of about 2,000 ft. There was no permanent water at this point, but some very tiny pools—one containing a *Copelatus* (*Liopterus*) *parvulus* beetle—had been formed in this region of heavy rainfall. Well behind the peak of Tantalus (Puu Lehua) at an elevation of over 1,000 ft. a number of rather pale brown *hawaiiense* nymphs were collected on March 10, 1935, along a tiny trickle and seepage of water on a steep

[32] Determined by Dr. Alexander Bierig.

slope, and that was for the most part concealed by a growth of *Commelina,* grass and other plants. I placed some of these nymphs in a cup of water where they proved to be very poor unwilling swimmers. They do however, occur in pools.

The nymph of *hawaiiense* feeds upon what the locality affords. Thus, dissections of the foregut of some of these rock-creeping insects taken from the steep little bank in Hering Valley showed that they fed very largely on the active cylindrical larvae of crane flies, *Limonia* (*Dicranomyia*) *grimshawi* (Alex.) and probably also on a smaller *L.* (*Dicranomyia*) sp. On two occasions a rock-creeping nymph was observed eating a cranefly larva. Aquatic oribatid mites are often consumed and *Scatella* flies, their larvae, and those of midges likewise form part of their food.

A note of November 19, 1933, may be of interest: Hering Valley, on a nearly horizontal part of a wet rock ledge adjoining the tiny stream, two large *hawaiiense* nymphs were walking about, even in the leaf-filtered sunlight. One of the pair, well raised on its legs, approached a small millipede (*Orthomorpha*) that was quiet save for the movement of a small group of its legs, and at which the nymph snapped in a half-hearted manner. A smaller nymph was seen on a wet and sloping rock nearby. Occasional wandering *Pheidole megacephala* ants sometimes attracted the attention of these *Megalagrion* nymphs, and remains of one of these ants were

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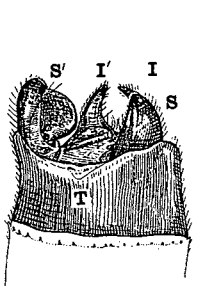
XVII

MEGALAGRION

Explanation of Plate

Figures of end of abdomen of adult males to show claspers, i.e., the superior appendages S and S′, and the inferior appendages I and I′. T indicates the dorsal or upper edge of the last abdominal segment. S′ indicates the superior appendage in nearly or quite in broadside view, as regards its inner surface.

109. *M. leptodemas,* Oahu.
110. *M. oceanicum,* Oahu.
111. *M. pacificum,* East Molokai.
112. *M. xanthomelas,* Oahu.
113. *M. amaurodytum* race *waianaeanum,* Oahu.
114. *M. koelense,* Oahu.
115. *M. nigrohamatum,* East Molokai.
116. *M. hawaiiense,* Oahu. A. with spine-like process.
117. *M. oahuense,* Oahu.



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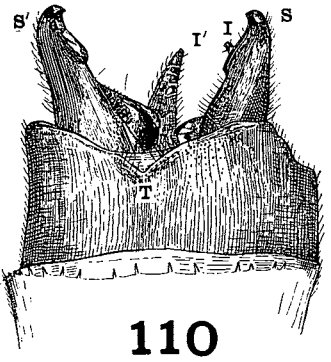

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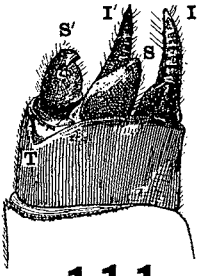

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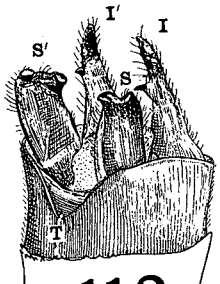

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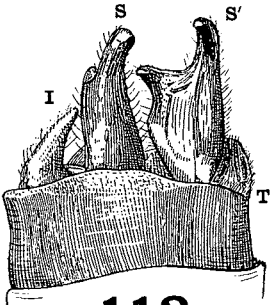

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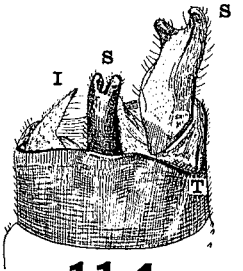

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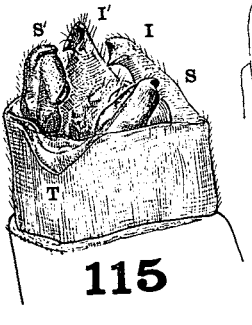

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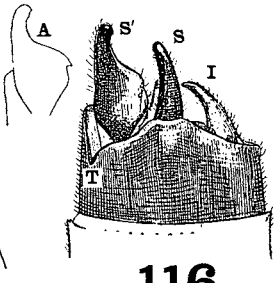

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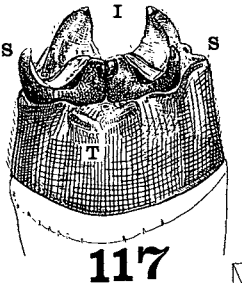

117

Megalagrion—end of abdomen of male adults.
T. indicates the dorsal side

found in the foregut of a large nymph. Jan. 14, 1934, other rock-creeping nymphs were seen on the wet rocks. Sometimes a nymph would have a film of water clinging to it, or it would be free of such. I placed a crane fly larva quite near a small damselfly nymph. The nymph seized this large larva but was unable to retain its grip. Not so however with a small water beetle (*Limnoxenus*) larva nearby. Although smaller than the fly larva, *Limnoxenus* seized it firmly in its sharp toothed jaws, and holding on bulldog-like, finally subdued it.

Eight partly-grown to last stage nymphs from the locality of March 10, behind the Peak of Tantalus, were dissected to find out what they had eaten, with the results as follows: one contained parts of three heads and tubercles of *Forcipomyia* sp. (*Ceratopogonidae*), the remnants of a small crustacean, probably *Philoscia,* and three oribatid mites; a second contained a young crustacean; the third a mite sp. and parts of a small crustacean; while the remaining five nymphs contained some fine undetermined material, or the crops were empty.

The lateral lobes of the labium of the *hawaiiense* nymph are provided with two moderately long bristles each, on their inner side, the first bristle being near the apex, the second slightly above the middle.[33] The bristles of the inner lobe are not conspicuous, there being a pair of more anterior bristle areas of a few shorter bristles, and a more posterior pair of areas of slightly longer bristles. The superior caudal appendages of the adult male may or may not have a small tooth on their lower side at the expanded portion (Plate XVII, 116 and A).

Sometimes we find a newly emerged damselfly, its body still pale and comparatively short, its wings yet silvery, resting on or near the skin that gave it birth and that clings so tenaciously to the boulder beside the stream. And close at hand, we might see a fully matured female *hawaiiense,* her slender abdomen showing dark metallic greenish and black with narrow and pale segmental bands, placing her eggs among wet plant debris in the shallowest of puddles.

M. hawaiiense is related to the generally larger and rather well distributed *M. deceptor* (McLach.).

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[33] A single nymph from 2,000 ft. elevation, windward Oahu, and that produced a rather light colored *M. hawaiiense* male has three well spaced bristles on the inner side of the lateral lobes.

Megalagrion deceptor (McLachlan).

Agrion deceptor Ann. and Mag. Nat. Hist., XII, p. 235, 1883. "All the Islands from Oahu to Hawaii inclusive (Perkins, 1913)."

This is a rather large damselfly that in size and coloration resembles a small specimen of *M. oceanicum*. In structure it is closely related to *M. hawaiiense*. It is at home well up in the mountains, extending up their slopes to an altitude of 6,000 ft. or more above sea-level and sometimes wandering far from the rocky canyon that gave it birth. Nymphs that seemed to be of this species were common in a small stream on the eastern slope of Mauna Kea, Hawaii, at an elevation of about 5,000 ft. above sea-level. About a dozen of these dagger-gilled nymphs showed from an examination of their foreguts that they had fed chiefly upon *Tanytarsus* fly larvae (Chironomidae) and oribatid mites.

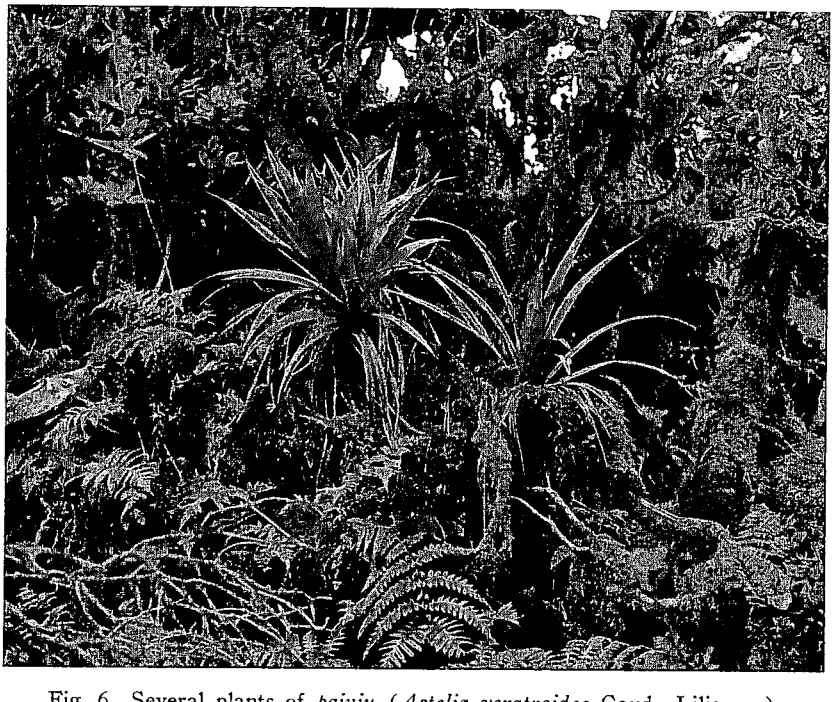

Fig. 6. Several plants of *painiu* (*Astelia veratroides* Gaud., Liliaceae) growing in the mossy forest on Mt. Kaala, Waianae Range, Oahu, at an elevation of about 4,000 feet. Nymphs of the damselfly *Megalagrion amaurodytum* live at the leaf bases of this plant.

Megalagrion that breed among the leaf-bases of certain plants.

We have several species of damselflies, the larvae of which are plant-dwellers. They occur in the upland rain forests where they are attached particularly to the *Astelia* or *painiu* and to the *Freycinetia* or *ieie*. The *Astelia* is a native lily of semi-epiphytic habit that grows on the ground (Text fig. 6), on moss, or fern-laden branches and trunks of forest trees or upon similarly covered rocks. The sword-like leaves, almost silky white beneath, of the *Astelia* lily are strongly V-shaped in section at their bases where one leaf rather openly overlapping another along the stem, afford splendid retreats and hunting grounds—when the plant is sufficiently large—for the nymphs of *Megalagrion*. Commencing at a lower level, in a zone less moist than that in which the *Astelia* occurs, the climbing screw-pine or *ieie, Freycinetia arborea* Gaud. (Pandanaceae) is to be seen twining itself on trees or, in zones of low plant growth, lifting a graceful head of glossy sword-like leaves from a snake-like stem from among the vegetation (Text figs. 7 and 8). Likewise the leaves of the *ieie* lack petioles and overlap at their base, and likewise do they collect between themselves an assortment of dead leaves, twigs, humus, etc., among which are to be found many small organisms, the food supply of the damselfly nymphs. Of moisture there is usually plenty among the leaf bases, and the nymphs, particularly the small ones, are often filmed over with water. But, except under very rainy conditions, water does not persist there, nor indeed does the nymph appear ordinarily to require any but an occasional wetting.[34] Quite rarely, as observed by Mr. O. H. Swezey, a damselfly nymph may be found at the petiole bases of the common *ti* plant (*Cordyline terminalis* Kunth).

[34] Hence the plant-dwelling nymphs of Hawaiian damselflies live under very different conditions than do those of the giant damselflies of tropical American forests where certain epiphytic species of the Bromeliaceae or pineapple family retain between many close-set leaf bases, an abundant and long-lasting, if not permanent supply of water in which the nymph, it seems, lives in a truly aquatic manner. These huge though slender damselflies slowly rising up or hovering, spectre-like in the forest, are one of the marvels of the insect world because of their excessive length of body, the abdomen sometimes exceeding five inches. In this connection it is appropriate to quote from Calvert's article "Studies on Costa Rican Odonata II—The Habits of the Plant-dwelling Larva of *Mecistogaster modestus*." (Entom. News, 22, 1911) on page 410, as follows: "The excessively long abdomen of the adults of *Mecistogaster* and its allies (*Megaloprepus, Microstigma, Pseudostigma, Anomisma*) may be a special adaptation to the life of their offspring in water-containing plants, since the abdomen of the larva of *M. modestus* is no longer proportionally, than in other Agrioinae. The space between the leaf of a bromeliad and the leaf next without decreases downward, and if *Mecistogaster's* eggs are deposited in the plant tissue in or near the contained water, in accordance with the general habit of Zygoptera, it would often be necessary for the female to reach far down into crevices possibly too narrow to admit of the entrance of her thorax and wings."

Even the wettest of our forests are, now and then, subject to dry spells, which, however, these plant-dwelling insects seem able to endure, and Dr. Perkins' observation (Fauna Hawaiiensis, II, Pt. I, p. 64, 1899) on the hardiness of these nymphs may well be quoted here, as follows: "These terrestrial nymphs are able to endure extreme drought. On one occasion when out shooting,

Fig. 7. *Ieie* or climbing screw-pine (*Freycinetia arborea* Gaud., Pandanaceae) growing on the crest of the Koolau Mountains behind Honolulu. The nymphs of several species of damselflies (*Megalagrion*) breed between the leaf bases of this plant. Elevation about 2,300 feet.

having no more convenient receptacle, I carried a number for the greater part of the day in an envelope. In the evening, although very dry, they were still quite lively. They were then placed in a tumbler of water, where they remained on the bottom, not being able to crawl up the sides. Here they remained for a day, apparently as happily as on dry land, when they were taken out and preserved."

The nymphs of three species of *Megalagrion* are plant-dwellers on Oahu, as follows: *M. amaurodytum* (Perk.) race *waianaeanum* (Perk.), *M. koelense* (Blackb.) and *M. asteliae* (Perk.).

These are closely related, more or less metallic black insects with some yellowish. *M. amaurodytum* race *waianaeanum* occurs on the high peaks of the Waianae Range, Oahu, where conditions are sufficiently moist for its nymph, which may be found between the leaf bases of *Astelia* and of *Freycinetia*. Eggs no doubt of this species were discovered in the midribs of *Freycinetia* leaves into which they had been inserted from the upper side. Nymphs were collected chiefly from winter to early summer, when they were found in several stages of growth. It is obvious, however, that both young and adults may be secured the year round. On February 9, 1930, the writer collected a number of nymphs from *Astelia* plants on Mt. Kaala, altitude 4,030 ft., the highest mountain on Oahu. These insects were either head down or head up between the bases, more commonly of the newer leaves, being partly or not in the little water there. The slender flightless cricket, *Leptogryllus forficulatus* (Brun.), were also plentiful in similar situations sometimes resting tête-à-tête with the damselfly nymphs. Some of these thickset nymphs were placed in water, in which they were awkward and appeared even uncomfortable. They could be induced to wriggle a little but really seemed unable to swim and they clung tenaciously to one's fingers as if fearing the element. The mature nymph is in general brownish or slightly greenish brown; wood brown on the back and dark along the sides of the abdomen. The short gills (Plate XIV, 87) are quite thick, more or less hair-fringed and finely to coarsely serrated on their lower edge. The median gill particularly is subject to considerable variation in this and in the other plant-dwellers that I have examined. It is most often falcate, sometimes considerably notched or emarginate below the sharp curved apex as though it had suffered injury there. This seems not to be the case, however, since bristles are present in such notches or emarginations (Plate XIV, 84 and 85, for *M. koelense* or *asteliae*).

A few adults were secured from these and other nymphs and, as is more usual with the Zygoptera, they issued in the morning.

The typical form, *M. amaurodytum,* was collected as nymphs in small numbers in late November 1933, from the fine *Astelia* plants in East Molokai at an altitude of over 2,000 ft. These nymphs—as measured from the front of the head to the extremity

of the gills—may attain a length of slightly over 20 mm. Their occasional pale green color may perhaps be due to a recent moult.

Megalagrion koelense (Blackb.) and *M. asteliae* (Perk.) are very closely allied species best separated by the rather slight differences in the male claspers. They average a little smaller than *M. amaurodytum. M. koelense* is found on Lanai, West Maui and Oahu; *M. asteliae* occurs on Oahu and Hawaii, and on Oahu may fly with *M. koelense.*

Fig. 8. More *ieie* vines (*Freycinetia arborea*) in the Koolau Mountains behind Honolulu. Elevation about 2,100 feet.

My field observations concern presumably only *M. koelense,* an insect conveniently found in the mountains behind Honolulu. The long narrow ridges that commence as buttresses from the edge of the city gradually attain higher altitudes, and then, rising more suddenly, merge into the serrated, knife-edged backbone of the range that drops so precipitously steep on its ribbed windward face. Among these moist heights then, from 2,000 to 3,100 feet above sea-level, a region of low, weathered vegetation, where sometimes occasional groups of the curious *Olapa* tree (*Cheirodendron*

platyphyllum Seem. Araliaceae) aspen-like, respond to the breeze by fluttering their broad shining leaves, with a noise like pattering raindrops, this damselfly is chiefly at home, its nymphs resting in the upright heads of the stout *ieie* vine, more rarely in *painiu,* and feeding upon convenient weaker neighbors of diverse groups that with it share the bases of the leaves.

Perkins has observed, in unpublished notes, this damselfly ovipositing in the leaves of the *ieie* (*Freycinetia*), and on March 24, 1935, I had that opportunity on Mt. Konahuanui, at an elevation of 3,100 ft. Here the *ieie* vine formed part of the vegetation that, on the one hand, clothing the great windward precipice with a dwarfish growth, reaches more generous proportions on the steep though more sheltered canyon slopes, on the other. Shortly before 10:00 a.m. a female damselfly was observed on a sharp ridge where many *ieie* vines raised their heads a foot or two above the ground. This chiefly bronzy-green and dull blackish insect, marked also with a little greenish yellow, would fly to one of the narrow, gracefully drooping *ieie* leaves that was situated rather outside in the whorl and alight on its sloping underside. Then she would feel about with the tip of her abdomen, the upper surface of the leaf immediately below her and rather near its base, and with abdomen extended cut slits directly in the midrib groove. One can see the end of her abdomen in muscular action, for the plant tissue is quite firm. The blade of the ovipositor (Plate XVIII, 121) is strongly saw-edged however, and punctures are soon made. ‘She

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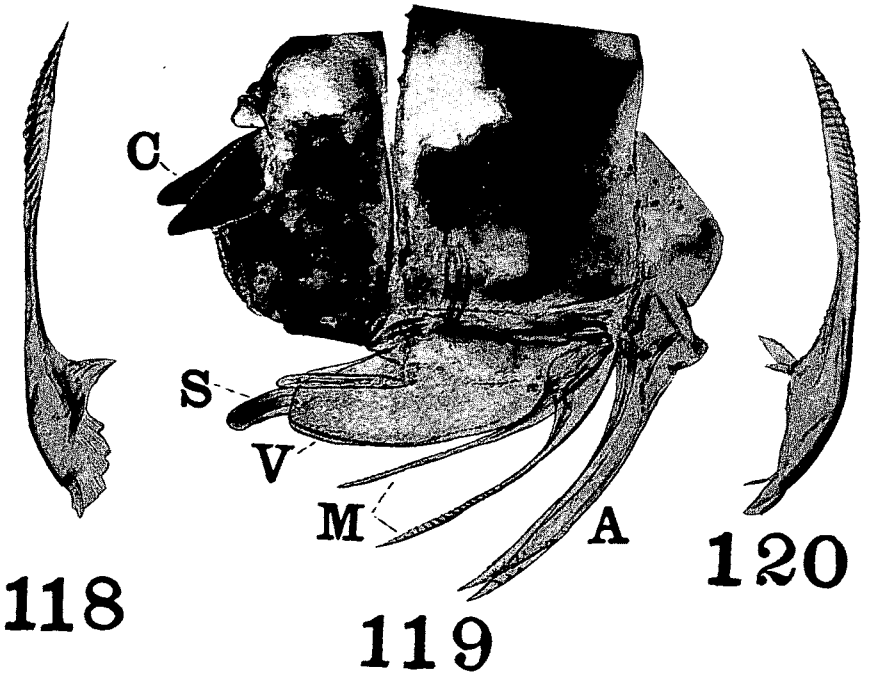
XVIII

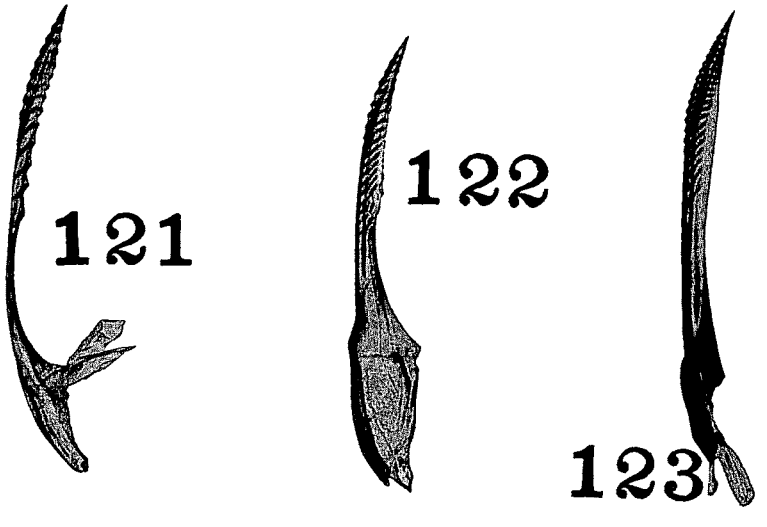
MEGALAGRION—Ovipositors

Explanation of Plate

118. *M. hawaiiense,* one of the paired median processes. Near Honolulu.
119. *M. amaurodytum* race *waianaeanum,* extremity of abdomen, somewhat compressed, to show components of ovipositor. A, anterior processes; M, median processes; V, valve; S, style. C, superior anal appendages. Oahu.
120. *M. deceptor,* median process. Oahu.
121. *M. koelense,* or *asteliae,* median process. Konahuanui, Oahu.
122. *M. oceanicum,* median process. Near Honolulu.
123. *M. oahuense,* median process. Near Honolulu.

Photographs by W. Twigg-Smith.





Megalagrion-ovipositors

deposited a small set of eggs in this leaf, rested briefly on a nearby bush and then commenced operations on another *ieie* plant.

Oviposition by this species or by *M. asteliae,* was again observed late in the morning of June 2, 1935, on the rain-gauge summit of Lanihuli, 2,700 ft., that precipitous ridge guarding the left side of the Nuuanu Pali, Honolulu. The damselfly alighting on a *Freycinetia* leaf, hung from its edge and underside, and slowly backed down it until the extremity of the abdomen touching the upper surface of the leaf immediately below naturally settled in its lowest part, i.e., the wide groove in which the midrib is situated. Oviposition took place at two inches or a little more from the exposed base of the leaf. The eggs are laid in the midrib, usually in pairs (Plate XII, 75) as if she realizes the advantage of making a single puncture through the hard surface serve for two eggs. Thus, oviposition in this species or group differs—as far as my observations go—from that of our species of other groups which insert but one egg through each puncture. The scars of the egg-punctures soon dry as dirty whitish membranous scabs, while the form of the eggs show as two diverging streaks. The scab eventually falls off, thereby exposing the darker pointed extremity of the egg, and the tissues about it darken so that older ovipositions—of which there are often one or more series on several leaves of the same plant—are quite conspicuous. The egg of *M. koelense,* or of *asteliae* (Plate XII, 72) is of the usual form, pale amber brown, dark at the pointed end and measures about one millimeter in length. The several little egg-groups of March 24 were brought to the warm laboratory in leaf sections and kept moist in a salve tin. From them, three nymphs were produced on April 15, making an incubation period of 22 days. An egg that was laid sometime prior to the above lots was placed freely in the water where in ten days it hatched perfectly. In several instances the pronymphal, or first stage (Plate XII, 73) was observed. This is characterized by a conical head and by having the appendages—antennae, mouth-parts, legs and gills—bound immovably to the body by an outer skin. The duration of this pronymphal stage was not determined, but it is always very short. The active young nymph is already of stout form (Plate XII, 71) and when immersed in water may wriggle the body vigorously, its legs outspread, but swims thus

very poorly. It is able to walk upside down from the surface film, a little.

None of the nymphs was reared through from early life. From time to time however, specimens that were well along in the last instar were placed between the occasionally wetted leaf-bases of an *ieie* head or among moistened towel paper and the broad folded *ti* (*Cordyline*) leaves, and thus a number were successfully brought to maturity. These issued usually in the morning, often quite early. A case of morning emergence was also noted in the field. The nymph of *M. koelense,* like that of *M. amaurodytum* of the Waianae Range, is a very ordinary looking insect; squat and thick-set with short gills,[35] of which at least the median one is more or less falcate (Plate XIV, 84 and 85). The color is chiefly greenish and dull brownish, the abdomen being a sort of wood brown with a broad dark stripe along the sides. Other specimens may be very dark.

Nymphs that have reached full growth and have stopped feeding are characterized—as in other species—by the swollen thorax and wing cases. Such a nymph may measure up to about 17.75 mm. including the gills. The bristles of the lateral, and of the median lobes are as in *M. amaurodytum waianaeanum,* i.e., usually 5 for the laterals and a few quite small ones for the median lobe.

While this insect seems to prefer the high wet ridges, nymphs may also be found in *ieie* plants growing even as low perhaps, as 1,000 ft. Food supply and of course, moisture exist in less quantity there than at greater altitudes, where only, I believe, does the insect really thrive. *Pheidole* ants are no doubt inimical to it at low levels, as they are to other insects as well.

Several nymphs frequently occur on one plant.

As a considerable variety of small organisms—millipeds, Crustacea, Acarina, Mollusca, Insecta, etc.—habitually live and often breed, between the leaf bases of *Astelia* and *Freycinetia,* it follows that the bill-of-fare of our plant-dwelling damselfly nymphs may be far from monotonous. A study of the various organisms associated with these two plants is an undertaking of considerable magnitude.[36] Many of these forms are too large or otherwise

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[35] For a study of the morphology of the caudal gills of *M.* (=*Agrion*) *asteliae,* see Tillyard, R. J., Proc. Linn. Soc. New South Wales, 1917, xlii, on pages 103-106.

[36] In this connection the reader is referred to an article by O. H. Swezey in this issue.

unsuited as food for the *Megalagrion* nymphs and some indeed, may prey upon them, particularly when quite young.[37]

The crops and gizzards of a considerable number of these plant-dwelling nymphs were examined to determine what they had fed upon, with the following results:

M. amaurodytum, from East Molokai, 2,400 ft., Nov. 29, 1935.

In *Astelia*—

1—A larva?, remains of an amphipod crustacean, a number of fern sporangia.

2—Remains of amphipod crustacean, part of a fern sporangium.

M. amaurodytum waianaeanum, from Waianae Mts., Oahu, 3,000-4,000 ft., April 19, 1931.

In *Astelia*—

1—Remains of a small spider.

2—Remains of a large oribatid mite (Acarina).

3—Portions of 3 very small amphipod Crustacea, 1 very small millipede part.

4—Small tortricid caterpillar (feeds on *Astelia*).

M. koclense probably Mt. Konahuanui, Oahu. 2,600-3,000 ft., March 24, 1935.

In *Freycinetia*—

1—Remains of a single little wasp (Mymaridae), probably *Polynema ciliata* Perk., parasitic in the eggs of the leafhopper, which oviposits in the leaves of *Freycinetia.*

2—Remains of a small crustacean, probably one of the Amphipoda.

3—Wasp remains—probably same as No. 1.

4—Parts of a small crustacean.

5—Wasp remains, probably same as No. 1.

6—Oribatid mite.

7—Mouth parts of a small homopterous bug.

8—Parts of a crustacean or a spider.

9—Mymarid wasp wing and parts of a small carabid beetle larva.

M. koelense, probably Mt. Olympus, Oahu, 2,000-2,400 ft., March 31, 1935.

In *Freycinetia*—

[37] High up in the Waianae Mountains, Oahu, in late June, 1935, the writer once saw a dark colored, crab-like spider that frequents the leaf bases of the *ieie,* with an apparently fully mature *M. amaurodytum* nymph in its grasp.

10—Dark leathery material with corneous piece, probably *Succinea* snail.

11—A brown mite (Acarina), part of *Succinea* ? shell, a small male nematocerous fly.

12—Small hymenopterous parasite, parts of a small carabid beetle larva, part of a small crustacean.

13—A holoptic, well-beaked head of probably a forcipomyiid fly (Ceratopogonidae).

14—Small hymenopterous parasite.

15—A collembolous insect, head of nematocerous fly larva, parts of a small isopod crustacean.

M. koelense probably—Mt. Lanihuli, Oahu, 2,500-2,700 ft., April 7, 1935.

In *Freycinetia*—

16—Remains of a crustacean.

17—Remains of a non-nematocerous fly.

18—Remains of an adult nematocerous fly, etc.

19—Two mymarid wasp wings and a thorax, probably *Polynema,* remains of a spider ?.

20—Remains of a carabid larva; small carabids may be very common in *Freycinetia.*

M. koelense probably, Kaluanui Valley, Oahu, 2,000 ft., February 22, 1931.

In *Freycinetia*—

21—A small *Megalagrion* nymph.

22—A small dark mite.

Besides these, the crops and gizzards of a very considerable number of other nymphs from the above localities were either empty or else contained material—usually of a fine character—which I could not identify.

Megalagrion oahuense (Blackburn).

Agrion oahuense Blackburn, T., Ann. and Mag. Nat. Hist., (5), XIV, 1884, p. 415 (♂).

Agrion oahuense, Perkins, R. C. L., Fauna Hawaiiensis, II, Pt. I, 1899, p. 74 (♀). High mountains of Oahu.

Megalagrion oahuense is a rather large damselfly of very slender form (Plate XIX, 124 ♂).[38] The colors are somewhat dull,

[38] Compare with *M. amaurodytum* race *waianaeanum* ♂, Plate XVI, Fig. 108.

particularly in the female and consist chiefly of red, brown and pitchy black with some bronzy green on the thorax. Structurally, this species stands well apart from the others; the male is readily identified by his peculiarly shaped terminal claspers (XVII, 117), the female by the tuft of tawny hair just behind each mesostigmal plate on the fore part of the mesothorax above (Text Fig. 9). And the isolated position of *M. oahuense* among its fellow damselflies is indicated also in its habits, which are very retiring, while the early stages though passed in decidedly wet situations are not truly aquatic.

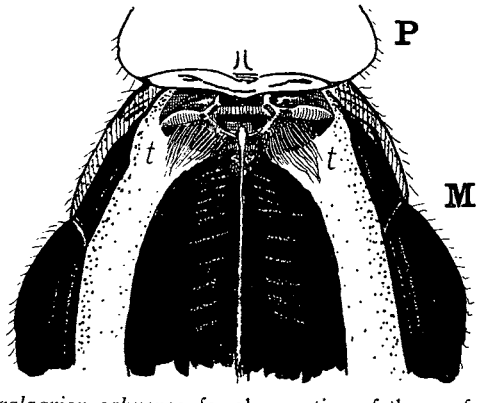


Fig. 9. *Megalagrion oahuense,* female; portion of thorax from above to show mesostigmal plate bearing posteriorly a hair tuft *tt*, on each side. P, pronotum; M, mesonotum.

Field observations on this insect were made in the Koolau Mountains just behind Honolulu, from early April 1935 into February 1936. Here it was found to range from an altitude of about 1,600 feet to far into the cloud zone of summits that rise to over 3,000 feet. During favorable weather a few individuals might be disturbed here and there along the trails where for the most part they were resting on low vegetation, darting up occasionally to capture minute flies, particularly Ceratopogonidae that occur in swarms in moist regions. And since *M. oahuense* was not observed in the vicinity of permanent water but on the fern covered ridges and upper slopes, and often indeed where the plant-dwelling *M. koelense* or *M. asteliae* damselfly occurred, a search was made among the leaf bases of the *ieie* vine and the *painiu* lily for its early stages. This search being unsuccessful, damp moss and

leafy trash were also examined, but likewise unavailingly. Then female *oahuense* were watched for egg-laying and finally, after a number of excursions to the mountains apparent oviposition among dead fern debris was observed. Several times previous to this observation however, female *oahuense* were confined in large glass jars supplied with wet moss, leaves, etc., in hopes that eggs would be laid. A few of these insects lived rather well in captivity, one surviving for 17 days. As a rule, they were fed once or twice daily, with soft portions of small Lepidoptera and of beetle larvae and pupae, the morsel being thrust up against the damselfly's mouth parts, which then often laid hold of it. A few times one or two of these captives placed the end of the body in contact with materials in the jar, but this action seemed too brief for oviposition. However, in looking over some of the trash in the jar a single damselfly egg was found. It was of a pale orange color, relatively stout and about 0.82 mm. long, being quite firmly secured for part of its length to a bit of moss. It failed to hatch.

My extensive search for the early stages of *oahuense,* eventually narrowed down the field of observation to an area hardly an acre in extent, the very head of a small canyon, leading from upper Manoa Valley and formed by the junction of a steep spur with the ridge that culminates in Mt. Olympus, elevation about 2,400 feet. This sloping hollow was perhaps 1,600 feet above sea level and here contained no water save occasionally tiny rain puddles of a very temporary nature. Its rather deforested slopes were covered with a thick tangled growth, some three feet tall, of *uluhi* or false staghorn fern (*Gleichenia linearis* (Burmann) Clark) (Text fig. 10). Here and there an *ieie* vine (*Freycinetia*) would thrust its glossy head of leaves through this cover, or an occasional tree fern (*Cibotium*) rose above it; ginger (*Zingiber zerumbet* Roscoe) mingled with fern along the bottom; almost a forest of *ti* (*Cordyline terminalis* Kunth) crowded luxuriantly at the lower end there, while such weeds as false vervain or *oi* (*Stachytarpheta dichotoma* Vahl), and the noxious thorny thimbleberry (*Rubus rosaefolius* Smith) occasionally intermingled. At the leaf bases of *Freycinetia* could be found an occasional nymph of *Megalagrion koelense,* or *asteliae,* the adults being more rarely seen. The large rather stout adults of *M. deceptor* were noted on two or three occasions, but adult *M. oahuense* were seen on most of my

numerous visits to this locality. On August 11, full 20 were observed, while on September 1, I noted at least 30. From this "peak" they became steadily less plentiful. On December 8, in a spell of sultry weather a recently emerged male was found, while on the showery morning of January 12, 1936, a female certainly not more than a day old and a well matured male were observed. On February 2, during a spell of cool weather, 4 males were noted.

Fig. 10. *Uluhi* fern (*Gleichenia linearis* (Burmann) Clark) in the mountains behind Honolulu. This cover is about 3 feet tall. The foreground has been cleared of the fern in a search for nymphs of the damselfly *Megalagrion oahuense*. Elevation about 1,500 feet.

Thus, the insect may be taken in the adult stage throughout the year.

In a letter to the writer, Dr. R. C. L. Perkins mentioned having seen *M. oahuense* adults about the dense growth of *uluhi,* and this indeed seems to be its favored habitat where the plant occurs, other ferns and plants substituting or filling in perhaps where the *uluhi* is not so abundant. My search for nymphs in the canyon head was long and arduous and resulted in the formation of paths, indentions and larger spaces in this difficult cover. While the upper portion of this fern was generally green and in a living state, beneath and largely cut off from the sunlight were browned fronds and dark stems, while yet nearer the damp ground the dead portions had so disintegrated as to form a sort of grating, or a mat reposing on the soil itself and there retaining considerable moisture.

Many times was an *M. oahuense* disturbed from its low perch near to or against the side of this *uluhi* cover; the insect would settle nearby and then sometimes in short flights descend to lower perches until it was close to the ground. Occasionally it would penetrate out of sight in this fern wall; more often however, it would dart at a tiny fly close at hand and even strike at some mite or insect on frond or stem and then settle down to eat its capture. Tiny ceratopogonid midges that breed in the wet fern trash hovered in gently shrill swarms all about this area and surely form a good part of the menu of *oahuense.* On one occasion a female *oahuense* was seen to follow a small moth until it had alighted on a fern, when it was immediately snatched off and leisurely devoured. And again, another female caught and devoured a young jumping spider (Attidae).

This damselfly is a noticeably tame insect, and time and again have I picked it off its perch by wings or abdomen. Several pairs were noted in copulo but none were ever seen in tandem.

The search for the nymph involved tearing openings through the *uluhi* cover—the sharp stiff broken fern stems making this work rather unpleasant—and the examination of wet trash. But the discovery one day of a freshly emerged adult and then of two others, a male and a female, on another day (in each case resting in or alongside the fern bank), lent encouragement to the chase. These three adults, though yet pallid and soft, were able to fly

and, having been disturbed from their perches, probably thereby lost for me the location of the exuviae from which they had issued. And very early on the afternoon of September 1, a single female was observed inserting her eggs—or attempting to do so—in *uluhi* debris, frond portions, etc., close to the ground alongside the edge of the fern wall.

These several observations clearly indicated that the nymph of *oahuense* was to be sought for among or under the moist debris that formed the lowest zone of the *uluhi* fern cover. Several loads of this fern trash were brought down to the laboratory and there examined with or without the aid of water, and in the smallest of these lots was found, on September 2, my first *oahuense* nymph, rather more than half grown. This productive debris had been gathered around the spot, close to the bed of the gulch, where the two freshly developed adults had been seen. This nymph measured nearly 12 mm. to the extremity of its short thick caudal gills. A fruitless search on September 7. Then on September 15, after an intermittent search of about 2½ hours a somewhat larger nymph nearly 14 mm. long was found on some wet muddy ground from which I had just removed the rather low *uluhi* cover. This was in the rather wide and shallow storm water channel of the gully, and on my eighth visit to the area. A number of subsequent trips yielded nothing.

These two *M. oahuense* nymphs were placed in separate glass

XIX

MEGALAGRION OAHUENSE

Explanation of Plate

124. Adult, male. Length 51.5 mm.

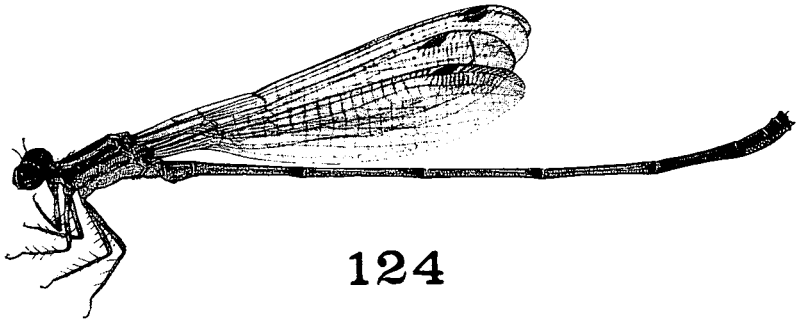
125. Nymph, female, from above; in penultimate stage. Length about 13 mm.

126. Same as Fig. 125, but from the underside.

127. Gills, median and one lateral (A) of Fig. 125; from side. Although the gills are thick and swollen, they are distinctly four-angled.

128. Labium, of Fig. 125, from the inside to show two large setae on each of the lateral lobes and two groups of small setae on the median lobe. The front margin of the median lobe is finely serrate.

Figs. 124-126, photographs by W. Twigg-Smith.



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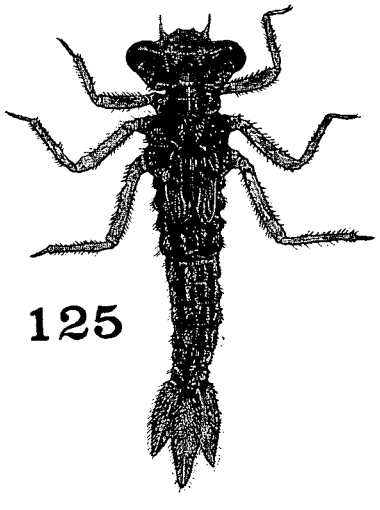

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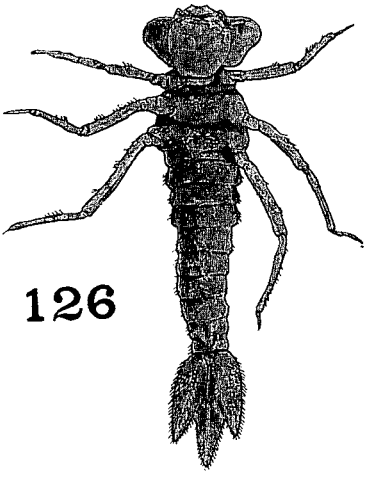

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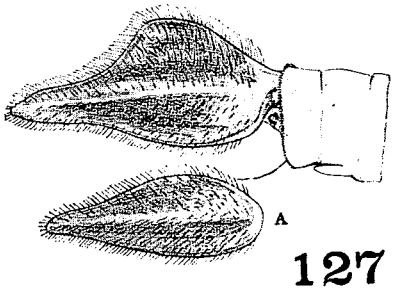

A

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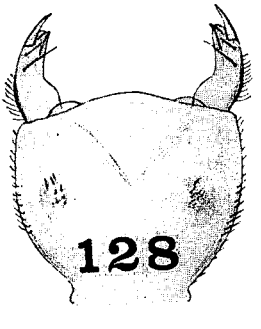

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Megalagrion oahuense

dishes containing wetted *uluhi* (*Gleichenia linearis*) trash in which were later introduced a number of very young sowbug Crustacea—as food. One nymph disappeared after a captivity of over a month. The second lived until December 8. During all this time it seemed not to have moulted, and to have slightly contracted rather than increased in size.

As a rule quiet, but when needs be a jerkily active creature that, earwig or scorpion-like, quickly bends forward its tail to ward off with thick gill tips any offending object there; a very indifferent wriggling swimmer when placed in water and not overfond of immersion in that element, this dull colored, roughened, almost woolly insect is indeed difficult to discover in its comparatively vast surroundings of brown soil and fine debris materials with which it blends so well. Found under very moist conditions, yet leading a terrestrial existence, the fine pale hairs on its body—in part arranged somewhat tuft-like on head and thorax, and as dorsal, subdorsal and lateral ridge-like rows on the segments of the abdomen, but above all, as an almost dense and silky covering on the three swollen tail gills—suggest an adaptation for better retaining moisture on the insect's body, even to the extent of forming a film of water, particularly about its tail end. The antennae are rather thick; 5 and 6 jointed in this, an immature specimen. Forward on the eyes is a curved row of pale spots. The general color is a sort of purplish red with a fine pale median line on part of the head and thorax, and a broader line on the abdomen. There is a whitish dorsal dash at the base of the median gill. The gills though swollen, are 4-angled, the median one most obviously so. The labium is short and broad with two setae on the lateral lobes and a small group on each side on the disc of the median lobe (XIX, 128).

The two nymphs captured were of an unkempt appearance due to the fine particles of materials collected among the hairs.

The one that survived captivity for nearly 3 months showed little inclination to feed, ignoring almost entirely the young Crustacea, pomace fly and nitidulid beetle larvae, minute millipeds, etc., some of which were forced to pass in review in close proximity to its face. Its feeding habits therefore remain unknown. There are available in the natural habitat of the nymph of *M. oahuense* a

host of small tender organisms, including copepod Crustacea and several species of nematocerous fly larvae.

The search for additional young of this damselfly will be continued, and some success may be anticipated in securing nymphs from eggs laid afield and in the laboratory. At the present writing, at least one nymph has thus been secured and although still quite small the median gill already shows a strongly arched profile.

The adult damselfly being a very low flyer thereby keeps pretty well out of the way of the large hawking dragonflies. Occasionally however, one of these insects becomes ensnared in the orb web of a spider among *uluhi* fern or other plant growth.

KEY FOR SEPARATING THE NYMPHS OF OAHUAN

MEGALAGRION

The following key for distinguishing the nymphs of Oahuan damselflies[39] is based mainly on specimens in the last stage of growth, although it will serve fairly well with younger individuals. The caudal gills will be found to vary within certain limits—as shown to some extent by the illustrations; likewise there may be variation in the development and the number of bristles or setae on the inner (superior) surface of the median and lateral lobes of the mentum. The marginal setae of the median lobe, and those along the inner eye margins are not used here; neither are the lateral carinae or ridges of the abdomen.

1. Gills large flattened leaflike, somewhat flexible, their tracheae with well marked pigmental bands and branching tree-like; marginal hairs beyond the base of the gills very fine, often more or less lacking; about 5-9 long setae on inner side of lateral lobes of mentum and at least one pair of long setae on the median lobe..... 2

   Not as above..... 3

2. Gills narrowed somewhat stem-like towards the base; spatulate; 5-6 setae on lateral lobes, and 1-3 pairs of long ones on median lobe. In mountain streams.....**M. leptodemas**

   Gills somewhat broader, hardly stem-like towards the base; at least 8 setae on lateral lobes and 4 or more pairs of long setae on the median lobe. Usually lowland forms, in reservoirs, etc...**M. xanthomelas**

[39] Except *M. pacificum* and *deceptor* with which I am not positively familiar.

3. Gills somewhat leaflike but tending to be swollen or saccate, tender and flexible, tips slender; obviously spinose or hairy along their entire margin. Median lobe of mentum as wide as head or nearly so, one long and sometimes one quite short seta towards apex of lateral lobes; short setae on median lobe. Often under stones in streams ..... **M. nigrohamatum** (Molokai), **nigrolineatum** (Oahu)

   Gills sword or dagger-shaped, or very short and thick, nearly or quite rigid; median lobe much narrower than head; not more than 5 setae on each lateral lobe 4

4. Larger, up to 25 mm. to extremity of gills; gills rather broadly dagger-shaped, strongly serrate and bristled along margins, usually a dark pigmented area beyond the middle, the apex pale; lateral lobes of mentum more commonly with 2 rather poorly developed subapical bristles, the lower one the smaller; median lobe with some quite short setae. In streams and on dripping wet banks ..... **M. oceanicum, M. blackburni**

   Smaller, usually less than 21 mm.; head comparatively wider; gills usually not so strongly and regularly serrate, and lacking a conspicuously pigmented area beyond the middle; at least 2 well developed setae on each lateral lobe 5

5. Gills narrow dagger-like, rather finely serrate, usually dusky before the pale apex; 2 well spaced bristles on each lateral lobe, the first bristle near apex, the second bristle a little above the middle length of the lobe; partly terrestrial ..... **M. hawaiiense**

   Gills thick and short, the median one commonly variably falcate; bristles of lateral lobes usually 5; living at the leaf bases of plants in wet forests ..... **M. amaurodytum waianaeanum, M. koelense** and **M. asteliae**

   Gills thickened, densely hairy, the median one conspicuously arched dorsally for its basal half or more; bristles of lateral lobe 2, the more apical one the shorter.[40] Living among moist *uluhi* fern trash in the mountains ..... **M. oahuense**

A single nymph taken at 2,000 ft. in the Koolau Mts. yielded what appears to be a small male *deceptor,* although much resembling *hawaiiense.* The nymph is like the latter but the lateral mental lobes have each 3 instead of 2 well-spaced setae.

[40] Based on a single nymph in the penultimate stage.

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